LEVEL #1

VOLUME 13, NO. 12,
DECEMBER 1981

A108290

AD A109583

THE SHOCK AND VIBRATION DIGEST

A PUBLICATION OF
THE SHOCK AND VIBRATION
INFORMATION CENTER
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

OFFICE OF
THE UNDER
SECRETARY
OF DEFENSE
FOR RESEARCH
AND
ENGINEERING

THE SHOCK AND VIBRATION DIGEST

Volume 13, No. 12
December 1981

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman
Vibration Institute
Suite 206
101 West 55th Street
Clarendon Hills, Illinois 60514

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of \$140.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendar year, beginning with the January issue. Back issues are available - Volumes 9 through 12 for \$15.00. Orders may be forwarded at any time to SVIC, Code 5804, Naval Research Laboratory, Washington, D.C. 20375. Issuance of this periodical is approved in accordance with the Department of the Navy Publications and Printing Regulations, NAVEXOS P-35.

A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

Code 5804, Naval Research Laboratory
Washington, D.C. 20375 $100.00

No copies

Henry C. Pusey
Director

Rudolph H. Volin

J. Gordan Showalter

Jessica P. Hileman

Elizabeth A. McLaughlin

SVIC NOTES

WHERE DID THAT NUMBER COME FROM?

Dynamic test requirements for equipment in vehicles often include numerical values and many users ask the question, "where did that number come from?" Interest in this subject is continuous but current efforts to revise MIL-STD-810, and requirements for test tailorability and for the disclosure of the rationale behind the numbers in test documents, have increased the awareness of this subject. Many methods have been used to set dynamic test requirements for vehicle equipment; it might be useful to briefly mention some of the more common of these.

First, if equipment is to be installed in an existing vehicle the establishment of test requirements might be simplified provided inputs from the vehicle to the item are available or can be measured.

If equipment is being developed for new vehicles it is only possible to establish preliminary test requirements at first because the equipment is usually developed before the vehicle exists. A typical orderly procedure includes the prediction of the expected dynamic environment followed by verification during field or laboratory tests once the prototype vehicle has become available. Many believe that preliminary test requirements should be slightly conservative to avoid the need to redesign the equipment and possible contractural difficulties if the operating environments turn out to be more severe than expected. Further details of this process have appeared in many of the *previous Shock and Vibration Bulletins* and papers on establishing qualification test requirements for airborne equipment will be published in the proceedings of the 53rd Meeting of the Advisory Group for Aerospace Research & Development (AGARD) Structures and Materials Panel which was recently held in the Netherlands.

Another method for setting dynamic test requirements for equipment in new vehicles is to use standards documents that contain guidelines that may be used to either derive test requirements or to establish the actual values of the dynamic test levels. Many prefer to use standards because they are convenient and often no other guidance is available. However, care must be taken in their use to avoid misinterpretation and this can only be done if the rationale behind the standard is known and understood. Many examples of the use of standards for establishing suitable dynamic test requirements for equipment in new vehicles are also available in the literature.

The foregoing are some of the more common methods for setting dynamic test requirements and other methods are available; some involve a combination of two or more of the methods that were previously mentioned, some are based on known physical limitations and still others are arbitrary. The most important requirements for any method for setting dynamic test requirements are that they must be as realistic as possible and that the rationale behind their numbers should be thoroughly documented.

R.H.V.

EDITORS RATTLE SPACE

DISTILLATION OF THE LITERATURE

Each year the twelfth issue of the DIGEST gives an indication of the volume of literature published in the shock and vibration area: there were almost 2700 abstracts published in the DIGEST in 1981. This represents a 40 percent increase in publications since 1978. At this rate of growth one wonders when the publishing system will go unstable and self destruct!

The increasing number of abstracts means that more and more information is being written in the shock and vibration field. More technology is thus available to the engineer trying to solve problems. Unfortunately, more is not always better. The large volume of literature means that the engineer will have to use valuable time attempting to identify pertinent articles and information. It is true that the abstract of an article or report can be retrieved as part of a subject or problem area, but this is only the beginning of the process of identifying what literature may be helpful in solving a problem or advancing a research and development project. The articles must be studied and analyzed to determine the available pertinent information. As the volume of literature increases, so does the time required to distill it. This brings us to the point of this editorial: the effort expended on literature reviews and distillation should increase in proportion to the growing volume of literature.

In past years the literature was distilled in textbooks and specialized technical books. This was and is a slow process. Today the distillation of the literature in book form is not keeping up with the growing volume of literature. The literature review section of the DIGEST is devoted to distillation of the literature – and is meant to provide an objective analysis of the literature. Many literature review articles are published in the DIGEST and in other journals, but other specific technical areas should also be reviewed. I feel that more effort should go into the writing of review articles. If you are interested in writing a review article, please contact the editors of the DIGEST.

R.L.E.

FINITE-ELEMENT MODELING OF LAYERED, ANISOTROPIC COMPOSITE PLATES AND SHELLS: A REVIEW OF RECENT RESEARCH

J.N. Reddy*

Abstract. This paper reviews finite element papers published in the open literature on the static bending and free vibration of layered, anisotropic, and composite plates and shells. The paper also contains a literature review of large-deflection bending and large-amplitude free oscillations of layered composite plates and shells. Non-finite element literature is also cited for continuity of the discussion.

In recent years composites, especially fiber-reinforced laminates, have found increasing application in many engineering structures. This is mainly due to two desirable features of fiber-reinforced composites: a high stiffness-to-weight ratio and the anisotropic material property that can be tailored through variation of the fiber orientation and stacking sequence of lamina – a feature that gives the designer flexibility. The increased use of fiber-reinforced composites as structural elements has generated considerable interest in the analysis of laminated (anisotropic) composite plates and shells.

Recent developments in the analysis of plates and shells laminated of fiber-reinforced materials indicate that thickness has a more pronounced effect on the behavior of composite laminates than on isotropic laminates. Classical thin-plate and thin-shell theories assume that normals to the midsurface before deformation remain straight and normal to the midsurface after deformation; the implication is that thickness shear deformation effects are negligible. As a result, natural frequencies calculated using the thin-plate theory are higher than those obtained by including transverse shear deformation effects. In addition, the transverse deflections predicted by thin-plate theory are lower than those predicted by shear deformable theory (SDT). Due to the low transverse shear modulus relative to the in-plane Young's moduli, transverse shear deformation effects are even more pronounced in composite laminates. Reliable prediction of the small deflection response characteristics of high modulus composite plates and shells therefore requires the use of shear deformable theories.

When the transverse deflections experienced by plates and shells are not small compared to laminate thickness, the interaction between membrane stresses and the curvatures – bending and shear – of the laminate must be considered. The interaction results in midplane stretching, which leads to nonlinear terms in the equations of motion. Thus, a more accurate prediction of deflections, stresses, and frequencies requires a solution of the laminate equations that can account for large deflections and thickness shear deformation.

LITERATURE REVIEW OF PLATES

Small-deflection theory of plates. A number of shear deformable theories for laminated plates have been proposed to date. The first theory for laminated isotropic plates is that of Stavsky [1]. The theory has been generalized to laminated anisotropic plates by Yang, Norris, and Stavsky [2]. Their work, called the Yang-Norris-Stavsky (YNS) theory, represents a generalization of Reissner-Mindlin plate theory for homogeneous isotropic plates to arbitrarily laminated anisotropic plates and includes shear deformation and rotatory inertia effects. A review of other theories, for example, the effective stiffness theory of Sun and Whitney [3], the higher-order theory of Whitney and Sun [4], and the three-dimensional elasticity theory of Srinivas et al [5-7], has been reviewed in [8]. It has been shown [3, 5, 9-13] that the YNS theory is adequate for predicting such overall behavior as transverse deflections and natural frequencies (first few modes) of laminated anisotropic plates.

***Professor, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061**

The first application of the YNS theory is apparently due to Whitney and Pagano [14], who presented closed-form solutions for symmetric and antisymmetric cross-ply and angle-ply rectangular plates under sinusoidal load distribution and for free vibration of antisymmetric angle-ply rectangular plates. Fortier and Rosettos [15] analyzed the free vibration of thick rectangular plates of unsymmetric cross-ply construction; Sinha and Rath [16] considered both vibration and buckling for the same type of plates. Following Whitney and Pagano [14], Bert and Chen [17] presented a closed-form solution for the free vibration of simply supported rectangular plates of antisymmetric angle-ply laminates.

Finite-element analysis of layered composite plates began with Pryor and Barker [18] and Barker, Lin, and Dana [19], who employed an element with seven degrees of freedom (three displacements, two rotations, and two shear slopes) per node to analyze thick laminated plates. Mau, Tong, and Pian [20] and Mau, Pian, and Tong [21] used the so-called hybrid-stress finite-element method to analyze thick composite plates. Noor and Mathers [22, 24] used finite element models based on a form of Reissner's plate theory -- i.e., mixed formulation -- to study the effects of shear deformation and anisotropy on the response of laminated anisotropic plates. One of the elements used had 80 degrees of freedom per element and thus required enormous computational resources. Hinton [24] used the so-called finite strip method to study the free vibration of layered cross-ply laminated plates. Mawenya and Davies [26] and Panda and Natarajan [27] used the quadratic shell element of Ahmad, Irons, and Zienkiewicz [28] to analyze the bending of thick multilayer plates. Spilker, Chou, and Orringer [29] used two hybrid-stress elements to study the static bending of layered composite plates. The number of degrees of freedom in one of the two elements is proportional to the number of layers; therefore, the core storage and execution time requirements for the element increase rapidly with the number of layers in the plate. Reddy [30] recently developed a simple and efficient finite element based on the YNS theory. The element contains three displacements and two bending slopes as degrees of freedom per node. The accuracy and convergence characteristics of the element have been investigated [31]. The element has been used successfully in the free vibration and thermoelastic analysis of ordinary and bimodulus (i.e., different elastic properties in tension and compression) layered composite plates [30-34].

Large-deflection theory of plates. Much of the research in the analysis of composite plates is limited to linear problems. This is perhaps due to the complexity of the nonlinear partial differential equation associated with the large-deflection theory of composite plates. Approximate solutions to the large-deflection theory (in the von Karman sense) of laminated composite plates have been attempted [35-43]. Chandra and Raju [38, 39] and Chia and Prabhakara [41, 42] employed the Galerkin method to reduce the governing nonlinear partial differential equations to an ordinary differential equation in time for the mode shape; the perturbation technique was used to solve the resulting equation. Zaghloul and Kennedy [40] used a finite-difference successive iterative technique in their analysis. In all of these studies with one exception [43], the transverse shear effects were neglected. The finite element employed by Noor and Hartley [43] includes the effect of transverse shear strains; however, it is algebraically complex and involves a large number of degrees of freedom per element. The use of such elements can thus be precluded in the nonlinear analysis of composite plates. Reddy and Chao [44, 45] recently adapted a shear deformable finite element [30] to the nonlinear bending of composite plates.

Analysis of nonlinear vibration of single-layer orthotropic plates has been done [46, 47]. Nowinski [48, 49] analyzed rectilinearly orthotropic plates of circular and triangular planforms using the Galerkin method; the effects of transverse shear deformation and rotatory inertia were not considered. Wu and Vinson [50] presented the dynamic analogue of Berger's equation of motion for an orthotropic plate, including the effect of transverse shear deformation and rotatory inertia; however, the solutions were restricted to transverse shear deformation. Mayberry and Bert [51] presented experimental as well as theoretical work on nonlinear vibration of laminated plates; the theoretical investigation was limited to a single-layer specially orthotropic rectangular plate with all four edges clamped and did not include the effect of transverse shear deformation and rotatory inertia. Nowinski [52] and others [53] used an assumed mode shape and Galerkin method to present a general equation for the nonlinear

analysis (i.e., large deflection and large amplitude free vibration) of orthotropic plates. Prabhakara and Chia [54] presented an analytical investigation of the nonlinear vibration of a rectangular orthotropic plate with all simply supported and all clamped edges. The effect of transverse shear and rotatory inertia on large amplitude vibration of composite plates was reported recently by Sathyamoorthy and Chia [55-57]. They used the Galerkin method and the Runge-Kutta numerical procedure.

In general, layered composite plates exhibit coupling between the in-plane displacements and the transverse displacement and shear rotations. For plates having layers stacked symmetrically with respect to the midplane, the bending-stretching coupling terms vanish and the problem is relatively simpler. Wu and Vinson [58] extended their earlier work [50] to deal with the nonlinear vibration of symmetrically stacked laminated composite plates. The first nonlinear vibration analysis of unsymmetrically laminated plates is that of Bennett [36], who considered simply supported (with immovable edges) angle-ply plates. Bert [37] used the thin plate theory of layered composite plates and the Galerkin method to investigate the nonlinear vibration of a rectangular plate arbitrarily laminated of anisotropic material. A multimode (two-term) solution for nonlinear vibration of unsymmetric all-clamped and all-simply supported angle-ply and cross-ply laminated plates was reported by Chandra and Basava Raju [38, 39, 59]. Chandra [39] used a one-term Galerkin approximation for the dynamic von Karman plate equations and the perturbation technique for the resulting ordinary equation in time to investigate the large-amplitude vibration of a cross-ply plate that is simply supported at two opposite edges and clamped at the other two edges. Prabhakara and Chia [54] presented an analytical investigation of the nonlinear free flexural vibrations of unsymmetric cross-ply and angle-ply plates with all-clamped and all-simply supported edges. The normal and tangential boundary forces in the plane of the plate were assumed to be zero. Reddy [60, 61] and Reddy and Chao [62] recently investigated the large-amplitude free vibration of layered composite plates using the finite-element method; they considered transverse shear and rotatory inertia effects. The finite-element studies [60, 62] are apparently the first to consider the nonlinear vibrations of layered anisotropic composite plates including transverse shear deformation. Additional references, especially those before 1980, can be found in survey articles [63-67].

LITERATURE REVIEW OF SHELLS

Small-deflection theory of shells. The first analysis that incorporated the bending-stretching coupling (due to unsymmetric lamination) in shells is that of Ambartsumyan [68, 69]. He assumed that the individual orthotropic layers were oriented so that the principal axes of material symmetry coincided with the principal coordinates of the shell reference surface. Thus, Ambartsumyan's work dealt with what is now known as laminated orthotropic shells rather than with laminated anisotropic shells. In laminated anisotropic shells the individual layers are generally anisotropic; in addition, the principal axes of material symmetry of the individual layers do not coincide with the principal coordinates of the shell.

In 1962 Dong, Pister, and Taylor [70] formulated a theory of thin shells laminated of anisotropic material. The theory is an extension of that developed by Stavsky [71] for laminated anisotropic plates to Donnell's shallow shell theory [78] of shells. Cheng and Ho [73] analyzed laminated anisotropic cylindrical shells using Flugge's shell theory [74]. Bert [75] combined Vlasov's shell theory [76] with the most general anisotrpic constitutive equations of Stavsky [71] to obtain an arbitrary shell geometry. A first-approximation theory for the unsymmetric deformation of nonhomogeneous, anisotropic, elastic cylindrical shells was derived by Widera and Chung [77]; they used the asymptotic integration of the elasticity equations. For a homogeneous, isotropic material the theory reduces to the Donnell equations [78]. An exposition of various shell theories is available [79].

All of the theories discussed above are based on Kirchoff-Love's hypotheses [72], in which transverse shear deformation is neglected. The effect of transverse shear deformation and transverse isotropy, as well as thermal expansion through the shell thickness have been considered by Zukas and Vinson [80] and Dong and Tso [81]. The theory used by Dong and Tso [81] is applicable only to layered, orthotropic, cylindrical shells; i.e., the orthotropic axes of each layer coincide with the coordinate axes of the shell. Whitney and Sun [82] developed a shear deformable

theory for laminated cylindrical shells that includes transverse shear deformation and transverse normal strain as well as expansional strains. Widera and Logan [83, 84] recently presented refined theories for nonhomogeneous anisotropic cylindrical shells.

As far as the finite-element analysis of shells is concerned, layered composite shells have not received the attention given to ordinary shells. The works of Dong [85] on statically-loaded orthotropic shell of revolution, Dong and Selna [86] on free vibration of the same, Wilson and Parsons [87] on static axisymmetric loading of arbitrarily thick orthotropic shells of revolution, and Schmit and Monforton [88] on laminated anisotropic cylindrical shells are the only ones that considered the finite-element method before 1970. The last reference is the only one that considered laminated anisotropic shells. During the 1970s there was increased interest in the finite-element analysis of bending and vibration of laminated anisotropic shells. A finite-element application in laminated anisotropic shells of arbitrary geometry is due to Thompson [89], who presented free vibration of general laminated anisotropic thin shells. Other finite-element analyses of layered anisotropic composite shells are available [90-100]; the effect of shear deformation was included in two papers [93, 100].

Large-deflection theory of shells. Despite the importance of nonlinear analyses of layered anisotropic shells, there is apparently no literature on the subject with the exception of the mixed finite-element analysis of Noor and Hartley [101] and recent work by Chang and Sawamiphakdi [102] and Reddy [103]. The work [102] utilizes a degenerated three-dimensional isoparametric element based on an updated Lagrangian description. In [103] a shear flexible finite element was developed based on a shell theory that combines various first-approximation shell theories [72, 78, 104-106]. The theory also accounts for large rotations.

CONCLUDING REMARKS

The bending and vibration analysis of layered anisotropic composite plates and shells is more complicated – due to bending-stretching coupling – than is the classical, isotropic, homogeneous analysis of plates and shells. Because of these complexities, the available literature is sparse, especially in the area of nonlinear analysis of shells, compared to that of ordinary plates and shells.

Although the first-order shear deformable theories of layered composite plates yield acceptable solutions for global response of plates and shells, the theories do not accurately predict stress singularities and higher-order frequencies. The questions relating to interlaminar stresses, edge effects, and delamination in composites [107-116] can be addressed only when higher-order, three-dimensional theories are employed [82, 117-120].

As the use of composites for high performance design applications increases, the need for more realistic theoretical and experimental prediction of the response characteristics of composite-material structures will become increasingly important.

ACKNOWLEDGMENT

Support of this work by the Structural Mechanics Program of the Air Force Office of Scientific Research (Grant AFOSR-81-0142) and the Structures Research Section of the NASA (Lewis Grant NAG. 3-208) is gratefully acknowledged.

REFERENCES

1. Stavsky, Y., "On the Theory of Symmetrically Heterogeneous Plates Having the Same Thickness Variation of the Elastic Moduli," Topics in Applied Mechanics, (Abir, D., Ollendorff, F., and Reiner, M., Eds.), American Elsevier (1965).

2. Yang, P.C., Norris, C.H., and Stavsky, Y., "Elastic Wave Propagation in Heterogeneous Plates," Intl. J. Solids Struct., 2, pp 665-684 (1966).

3. Sun, C.T. and Whitney, J.M., "Theories for the Dynamic Response of Laminated Plates," AIAA J., 11, pp 178-183 (1973).

4. Whitney, J.M. and Sun, C.T., "A Higher Order Theory for Extensional Motion of Laminated Composites," J. Sound Vib., 30, pp 85-97 (1973).

5. Srinivas, S. and Rao, A.K., "Bending, Vibration and Buckling of Simply Supported Thick Orthotropic Rectangular Plates and Laminates," Intl. J. Solids Struc., 6, pp 1463-1481 (1970).

6. Srinivas, S., Joga Rao, C.V., and Rao, A.K., "An Exact Analysis for Vibration of Simply Supported Homogeneous and Laminated Thick Rectangular Plates," J. Sound Vib., 12, pp 187-199 (1970).

7. Hussainy, S.A. and Srinivas, S., "Flexure of Rectangular Composite Plates," Fibre Sci. Tech., 8, pp 59-76 (1975).

8. Bert, C.W., "Analysis of Plates," Structural Design and Analysis, Part I (Chamis, C.C., Ed.), Academic Press, (1974).

9. Pagano, N.J., "Exact Solutions for Composite Laminates in Cylindrical Bending," J. Composite Matls., 3 (3), pp 398-411 (1969).

10. Pagano, N.J., "Exact Solutions for Rectangular Bidirectional Composites and Sandwich Plates," J. Composite Matls., 4, pp 20-34 (1970).

11. Pagano, N.J. and Hatfield, S.J., "Elastic Behavior of Multilayer Bidirectional Composites," AIAA J., 10, pp 931-933 (1972).

12. Whitney, J.M., "The Effect of Transverse Shear Deformation on the Bending of Laminated Plates," J. Composite Matls., 3 (3), pp 534-547 (1969).

13. Mau, S.T., "A Refined Laminated Plate Theory," J. Appl. Mechanics, Trans. ASME, 40, pp 606-607 (1973).

14. Whitney, J.M. and Pagano, N.J., "Shear Deformation in Heterogeneous Anisotropic Plates," J. Appl. Mechanics, Trans. ASME, 37, pp 1031-1036 (1970).

15. Fortier, R.C. and Rossettos, J.N., "On the Vibration of Shear Deformable Curved Anisotropic Composite Plates," J. Appl. Mech., Trans. ASME, 40, pp 299-301 (1973).

16. Sinha, P.K. and Rath, A.K., "Vibration and Buckling of Cross-Ply Laminated Circular Cylindrical Panels," Aeronaut. Quart., 26, pp 211-218 (1975).

17. Bert, C.W. and Chen, T.L.C., "Effect of Shear Deformation on Vibration of Antisymmetric Angle-Ply Laminated Rectangular Plates," Intl. J. Solids Struc., 14, pp 465-473 (1978).

18. Pryor, C.W., Jr. and Barker, R.M., "A Finite Element Analysis Including Transverse Shear Effects for Applications to Laminated Plates," AIAA J., 9, pp 912-917 (1971).

19. Barker, R.M., Lin, F.T., and Dana, J.R., "Three Dimensional Finite-Element Analysis of Laminated Composites," Natl. Symp. Computerized Structural Anal. Des., George Washington Univ. (1972).

20. Mau, S.T., Tong, P., and Pian, T.H.H., "Finite Element Solutions for Laminated Thick Plates," J. Composite Matls., 6, pp 304-311 (1972).

21. Mau, S.T., Pian, T.H.H., and Tong, P., "Vibration Analysis of Laminated Plates and Shells by a Hybrid Stress Element," AIAA J., 11, pp 1450-1452 (1973).

22. Noor, A.K., "Free Vibrations of Multilayered Composite Plates," AIAA J., 11, pp 1038-1039 (1973).

23. Noor, A.K. and Mathers, M.D., "Anisotropy and Shear Deformation in Laminated Composite Plates," AIAA J., 14, pp 282-285 (1976).

24. Noor, A.K. and Mathers, M.D., "Finite Element Analysis of Anisotropic Plates," Intl. J. Numer. Methods Engr., 11, pp 289-307 (1977).

25. Hinton, E., "A Note on a Thick Finite Strip Method for the Free Vibration of Laminated Plates," Intl. J. Earthquake Engr. Struct. Dynam., 4, pp 511-514 (1976).

26. Mawenya, A.S. and Davies, J.D., "Finite Element Bending Analysis of Multilayer Plates," Intl. J. Numer. Methods Engr., 8, pp 215-225 (1974).

27. Panda, S.C. and Natarajan, R., "Finite Element Analysis of Laminated Composite Plates," Intl. J. Numer. Methods Engr., 14, pp 69-79 (1979).

28. Ahmad, S., Irons, B.M., and Zienkiewicz, O.C., "Analysis of Thick and Thin Shell Structures by Curved Finite Elements," Intl. J. Numer. Methods Engr., 2, pp 419-451 (1970).

29. Spilker, R.L., Chou, S.C., and Orringer, O., "Alternate Hybrid Stress Elements for Analysis of Multilayer Composite Plates," J. Composite Matls., 11, pp 51-70 (1977).

30. Reddy, J.N., "A Penalty Plate-Bending Element for the Analysis of Laminated Anisotropic Composite Plates," Intl. J. Numer. Methods Engr., 15, pp 1187-1206 (1980).

31. Reddy, J.N. and Chao, W.C., "A Comparison of Closed-Form and Finite Element Solutions of Thick Laminated Anisotropic Rectangular Plates," Nuclear Engr. Des., 64 (1981).

32. Reddy, J.N., "Free Vibration of Antisymmetric, Angle-Ply Laminated Plates, Including Transverse Shear Deformation by the Finite Element Method," J. Sound Vib., 66 (4), pp 565-576 (1979).

33. Reddy, J.N. and Bert, C.W., "Analyses of Plates Constructed of Fiber-Reinforced Bimodulus Materials," Mechanics of Bimodulus Materials, (Bert, C.W., Ed.), AMD Vol. 33, ASME, pp 29-37 (1979).

34. Reddy, J.N. and Chao, W.C., "Finite-element Analysis of Laminated Bimodulus Composite-Material Plates," Computers Struc., 12, pp 245-251 (1980).

35. Whitney, J.M. and Leissa, A.W., "Analysis of Heterogeneous Anisotropic Plates," J. Appl. Mechanics, Trans. ASME, 36, pp 261-266 (1969).

36. Bennett, J.A., "Nonlinear Vibration of Simply Supported Angle Ply Laminated Plates," AIAA J., 9, pp 1997-2003 (1971).

37. Bert, C.W., "Nonlinear Vibration of a Rectangular Plate Arbitrarily Laminated of Anisotropic Material," J. Appl. Mechanics, Trans. ASME, 40, pp 452-458 (1973).

38. Chandra, R. and Raju, B.B., "Large Amplitude Flexural Vibration of Cross-Ply Laminated Composite Plates," Fibre Sci. Tech., 8, pp 243-263 (1975).

39. Chandra, R., "Large Deflection Vibration of Cross-Ply Laminated Plates with Certain Edge Conditions," J. Sound Vib., 47 (4), pp 509-514 (1976).

40. Zaghloul, S.A. and Kennedy, J.B., "Nonlinear Analysis of Unsymmetrically Laminated Plates," ASCE J. Engr. Mechanics Div., 101 (EM3), pp 169-185 (1975).

41. Chia, C.Y. and Prabhakara, M.K., "Large Deflection of Unsymmetric Cross-Ply and Angle-Ply Plates," J. Mech. Engr. Sci., 18 (4), pp 179-183 (1976).

42. Chia, C.Y. and Prabhakara, M.K., "A General Mode Approach to Nonlinear Flexural Vibrations of Laminated Rectangular Plates," J. Appl. Mechanics, Trans. ASME, 45, pp 623-628 (1978).

43. Noor, A.K. and Hartley, S.J., "Effect of Shear Deformation and Anisotropy on the Non-Linear Response of Composite Plates," Developments in Composite Materials - 1, (Holister, G., Ed.), Appl. Sci. Publ., Barking, Essex, England, pp 55-65 (1977).

44. Reddy, J.N. and Chao, W.C., "Large Deflection and Large Amplitude Free Vibrations of Laminated Composite Material Plates," Computers Struc., 13 (2), pp 341-347 (1981).

45. Reddy, J.N. and Chao, W.C., "Non-Linear Bending of Thick Rectangular, Laminated Composite Plates," Intl. J. Nonlin. Mechanics (1981).

46. Ambartsumyan, S.A., Theory of Anisotropic Plates (English Translation), Technomic, Stamford, CT (1970).

47. Hassert, J.E. and Nowinski, J.L., "Nonlinear Transverse Vibration of a Flat Rectangular Orthotropic Plate Supported by Stiff Rig," Proc. 5th Intl. Symp. Space Tech. Sci., Tokyo, pp 561-570 (1962).

48. Nowinski, J.L., "Nonlinear Vibrations of Elastic Circular Plates Exhibiting Rectilinear Orthotropy, Z. Angew Meth. Physik, 14, pp 112-124 (1963).

49. Nowinski, J.L. and Ismail, I.A., "Large Oscillations of an Anisotropic Triangular Plate," J. Franklin Inst., 280, pp 417-424 (1965).

50. Wu, C.I. and Vinson, J.R., "On the Nonlinear Oscillations of Plates Composed of Composite Materials," J. Composite Matls., 3, pp 548-561 (1969).

51. Mayberry, B.L. and Bert, C.W., "Experimental Investigation of Nonlinear Vibrations of Laminated Anisotropic Panels, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 39, Pt 3, pp 191-199 (1969).

52. Nowinski, J.L., "Nonlinear Oscillations of Anisotropic Plates under Large Initial Stress," Proc. 10th Cong. Theoret. Appl. Mechanics, Madras, India, pp 13-30 (1965).

53. Sathyamoorthy, M. and Pandalai, K.A., "Nonlinear Flexural Vibrations of Orthotropic Rectangular Plates," J. Aeronaut. Soc. India, 22, pp 264-266 (1970).

54. Prabhakara, M.K. and Chia, C.Y., "Nonlinear Flexural Vibrations of Orthotropic Rectangular Plates," J. Sound Vib., 52, pp 511-518 (1977).

55. Sathyamoorthy, M. and Chia, C.Y., "Non-Linear Vibration of Anisotropic Rectangular Plates Including Shear and Rotatory Inertia," Fibre Sci. Tech., 13, pp 337-361 (1980).

56. Sathyamoorthy, M. and Chia, C.Y., "Effect of Transverse Shear and Rotatory Inertia on Large Amplitude Vibration of Anisotropic Skew Plates; Part 1: Theory," J. Appl. Mechanics, Trans. ASME, 47, pp 128-132 (1980).

57. Sathyamoorthy, M. and Chia, C.Y., "Effect of Transverse Shear and Rotatory Inertia on Large Amplitude Vibration of Anisotropic Skew Plates; Part 2: Numerical Results," J. Appl. Mechanics, Trans. ASME, 47, pp 133-138 (1980).

58. Wu, C.I. and Vinson, J.R., "Nonlinear Oscillations of Laminated Specially Orthotropic Plates with Clamped and Simply Supported Edges," J. Acoust. Soc. Amer., 49, pp 1561-1567 (1971).

59. Chandra, R. and Basava Raju, B., "Large Deflection Vibration of Angle Ply Laminated Plates," J. Sound Vib., 40, pp 393-408 (1975).

60. Reddy, J.N., "Nonlinear Vibration of Layered Composite Plates Including Transverse Shear and Rotatory Inertia," 1981 ASME Vib. Conf., Hartford, CT (Sept 20-23, 1981).

61. Reddy, J.N., "Analysis of Layered Composite Plates Accounting for Large Deflections and Transverse Shear Strains," Recent Advances in Nonlinear Computational Mechanics (E. Hinton et al., Eds.), Pineridge Press, Swansea, United Kingdom (to appear).

62. Reddy, J.N. and Chao, W.C., "Nonlinear Oscillations of Laminated Anisotropic, Thick, Rectangular Plates," Struc. Matls. Conf., 1981 Winter Ann. Mtg. ASME, Washington, DC.

63. Bert, C.W., "Dynamics of Composite and Sandwich Panels," Part I, Shock Vib. Dig., 8 (10), pp 37-48 (Oct 1976).

64. Bert, C.W., "Dynamics of Composite and Sandwich Panels," Part II, Shock Vib. Dig., 8 (11), pp 15-24 (Nov 1976).

65. Bert, C.W., "Vibration of Composite Structures," Proc. Intl. Conf. Recent Advances Struc. Dynam., Univ. of Southampton, Southampton, England (July 7-11, 1980).

66. Reddy, J.N., "Finite Element Modeling of Structural Vibrations: A Review of Recent Advances," Shock Vib. Dig., 11 (1), pp 25-39 (Jan 1979).

67. Leissa, A.W., "Advances in Vibration, Buckling and Postbuckling Studies on Composite Plates," Intl. Conf. Composite Struc., Paisley, Scotland (Sept 16-18, 1981).

68. Ambartsumyan, S.A., "Calculation of Laminated Anisotropic Shells," Izvestiia Akademiia Nauk Armenskoi SSR, Ser. Fiz. Mat. Est. Tekh. Nauk., 6 (3), p 15 (1953).

69. Ambartsumyan, S.A., Theory of Anisotropic Shells. Moscow, 1961; English translation, NASA TT F-118 (May 1964).

70. Dong, S.B., Pister, K.S., and Taylor, R.L., "On the Theory of Laminated Anisotropic Shells and Plates," J. Aerospace Sci., 29, pp 969-975 (1962).

71. Stavsky, Y., "Bending and Stretching of Laminated Anisotropic Plates," ASCE J. Engr. Mechanics Div., 87 (EM6), p 31 (1961).

72. Love, A.E.H., "On the Small Free Vibrations and Deformations of the Elastic Shells," Philosoph. Trans. Royal Soc. (London), Ser. A, 17, pp 491-546 (1888).

73. Cheng, S. and Ho, B.P.C., "Stability of Heterogeneous Aeolotropic Cylindrical Shells under Combined Loading," J. Amer. Inst. Aeronaut. Astronaut., 1 (4), pp 892-898 (1963).

74. Flugge, W., Stresses in Shells, Springer-Verlag, Berlin (1960).

75. Bert, C.W., "Structural Theory for Laminated Anisotropic Elastic Shells," J. Composite Matls., 1, pp 414-423 (1967).

76. Vlasov, V.Z., General Theory of Shells and Its Applications in Engineering, Moscow, 1949; English Translation, NASA TT F-99 (1964).

77. Widera, O.E. and Chung, S.W., "A Theory for Non-Homogeneous Anisotropic Cylindrical Shells," Z. Angew Math. Physik, 21, pp 378-399 (1970).

78. Donnell, L.H., "Stability of Thin Walled Tubes in Torsion," NACA Rep. 479 (1933).

79. Bert, C.W., "Analysis of Shells," Analysis of Performance of Composites, (Broutman, L.G., Ed.), Wiley, NY, Ch. 5, pp 207-258 (1980).

80. Zukas, J.A. and Vinson, J.R., "Laminated Transversely Isotropic Cylindrical Shells," J. Appl. Mechanics, Trans. ASME, pp 400-407 (1971).

81. Dong, S.B. and Tso, F.K.W., "On a Laminated Orthotropic Shell Theory Including Transverse Shear Deformation," J. Appl. Mechanics, Trans. ASME, 39, pp 1091-1097 (1972).

82. Whitney, J.M. and Sun, C.T., "A Refined Theory for Laminated Anisotropic, Cylindrical Shells," J. Appl. Mechanics, 41, pp 471-476 (1974).

83. Widera, G.E.O. and Logan, D.L., "Refined Theories for Nonhomogeneous Anisotropic Cylindrical Shells; Part I: Derivation," ASCE J. Engr. Mechanics Div., 106 (EM6), pp 1053-1074 (1980).

84. Logan, D.L. and Widera, G.E.O., "Refined Theories for Nonhomogeneous Anisotropic Cylindrical Shells; Part II: Application," ASCE J. Engr. Mechanics Div., 106 (EM6), pp 1075-1090 (1980).

85. Dong, S.B., "Analysis of Laminated Shells of Revolution," ASCE J. Engr. Mechanics Div., 92 (EM6), p 135 (1966).

86. Dong, S.B. and Selna, L.G., "Natural Vibrations of Laminated Orthotropic Shells of Revolution," J. Composite Matls., 4 (1), pp 2-19 (1970).

87. Wilson, E.A. and Parsons, B., "The Finite Element Analysis of Filament-Reinforced Axisymmetric Bodies," Fibre Sci. Tech., 2, pp 155-156 (1969).

88. Schmit, L.A. and Monforton, G.R., "Finite Element Analysis of Sandwich Plate and Laminate Shells with Laminated Faces," J. Amer. Inst. Aeronaut. Astronaut., 8, pp 1454-1461 (1970).

89. Thompson, G.L., "Finite-Element Analysis for Free Vibration of General Anisotropic Laminated Thin Shells," Composite Materials in Engineering Design (Proc. 6th St. Louis Symp., May 1972), (Noton, B.R., Ed.), ASM (1973).

90. Padavon, J., "Quasi-Analytical Finite Element Procedures for Axisymmetric Anisotropic Shells and Solids," Computers Struc., 4, pp 467-483 (1974).

91. Padavon, J., "Numerical Analysis of Asymmetric Frequency and Buckling Eigenvalues of Prestressed Rotating Anisotropic Shells of Revolution," Computers Struc., 5, pp 145-154 (1975).

92. Padavon, J., "Travelling Waves Vibrations and Buckling of Rotating Anisotropic Shells of Revolution by Finite Elements," Intl. J. Solids Struc., 11, pp 1367-1380 (1975).

93. Noor, A.K. and Mathers, M.D., "Shear-Flexible Finite-Element Models of Laminated Composite Plates and Shells," NASA TN D-8044, Langley Res. Ctr., Hampton, VA.

94. Noor, A.K. and Camin, R.A., "Symmetry Considerations for Anisotropic Shells," Computer Methods Appl. Mechanics Engr., 9, pp 317-335 (1976).

95. Noor, A.K. and Andersen, C.M., "Mixed Isoparametric Finite Element Models of Laminated Composite Shells," Computer Methods Appl. Mechanics Engr., 11 (3), pp 255-280 (1977).

96. Panda, S.C. and Natarajan, R., "Finite Element Analysis of Laminated Shells of Revolution," Computers Struc., 6, pp 61-64 (1976).

97. Shivakumar, K.N. and Krishna Murty, A.V., "A High Precision Ring Element for Vibrations of Laminated Shells," J. Sound Vib., 58 (3), pp 311-318 (1978).

98. Rao, K.P., "A Rectangular Laminated Anisotropic Shallow Thin Shell Finite Element," Computer Methods Appl. Mechanics Engr., 15, pp 13-33 (1978).

99. Siede, P. and Chang, P.H.H., "Finite Element Analysis of Laminated Plates and Shells," NASA CR-157106 (1978).

100. Hsu, Y.S., Reddy, J.N., and Bert, C.W., "Thermoelasticity of Circular Cylindrical Shells Laminated of Bimodulus Composite Materials," J. Thermal Stresses, 4 (2) (1981).

101. Noor, A.K. and Hartley, S.J., "Nonlinear Shell Analysis via Mixed Isoparametric Elements," Computers Struc., 7, pp 615-626 (1977).

102. Chang, T.Y. and Sawamiphakdi, K., "Large Deformation Analysis of Laminated Shells by Finite Element Method," Computers Struc., 13, pp 331-340 (1981).

103. Reddy, J.N., "A Finite-Element Analysis of Large-Deflection Bending of Laminated Anisotropic Shells," Symp. Nonlin. Finite-Element Analysis Shells, 1981 Winter Ann. Mtg. ASME, Washington, DC (Nov 15-20, 1981).

104. Sanders, J.L., Jr., "An Improved First Approximation Theory for Thin Shells," NASA TR R-24 (June 1959).

105. Loo, T.T., "An Extension of Donnell's Equation for a Circular Cylindrical Shell," J. Aeronaut. Sci., 24, pp 390-391 (1957).

106. Morley, L.S.D., "An Improvement of Donnell's Approximation of Thin-Walled Circular Cylinders," Quart. J. Mech. Appl. Math., 8, pp 89-99 (1959).

107. Hayashi, T., "Analytical Study of Interlaminar Shear Stresses in a Laminated Composite Plate," Trans. Japan Soc. Aero. Engr. Space Sci., 10 (47), p 43 (1967).

108. Pagano, N.J., "Stress Fields in Composite Laminates," Intl. J. Solids Struc., 14, pp 385-400 (1978).

109. Pagano, N.J., "Free Edge Stress Fields in Composite Laminates," Intl. J. Solids Struc., 14, pp 401-406 (1978).

110. Wang, A.S.D. and Crossman, F.W., "Some New Results on Edge Effect in Symmetric

Composite Laminates, J. Composite Matls., 8, pp 92-106 (1977).

111. Salamon, N.J., "Interlaminar Stresses in a Layered Composite Laminate in Bending," Fibre Sci. Tech., 11, pp 305-317 (1978).

112. Wang, S.S. and Choi, I., "Boundary Layer Thermal Stresses in Angle-Ply Composite Laminates," Modern Developments in Composite Materials and Structures, (Vinson, J.R., Ed.), ASME, pp 315-341 (1979).

113. Wang, S.S., "Edge Delamination in Angle-Ply Composite Laminates," Proc. 22nd AIAA/ASME/SAE Struc., Struc. Dynam., Matls. Conf., Atlanta, GA, pp 473-484 (1981).

114. Spilker, R.L. and Chou, S.C., "Edge Effects in Symmetric Composite Laminates: Importance of Satisfying the Traction-Free-Edge Condition," J. Composite Matls., 14, pp 2-20 (1980).

115. Raju, I.S. and Crews, J.H., Jr., "Interlaminar Stress Singularities at a Straight Free Edge in Composite Laminates," NASA Tech. Memo. 81876, Langley Res. Ctr., Hampton, VA (1980).

116. Raju, I.S., Whitcomb, J.D., and Goree, J.G., "A New Look at Numerical Analysis of Free-Edge Stresses in Composite Laminates," NASA Tech. Paper 1751, Langley Res. Ctr., Hampton, VA (1980).

117. Lo, K.H., Christensen, R.M., and Wu, E.M., "A Higher-Order Theory of Plate Deformation; Part 1: Homogeneous Plates," J. Appl. Mechanics, Trans. ASME, 44, pp 662-668 (1977).

118. Lo, K.H., Christensen, R.M., and Wu, E.M., "A Higher-Order Theory of Plate Deformation; Part 2: Laminated Plates," J. Appl. Mechanics, Trans. ASME, 44, pp 669-676 (1977).

119. Spilker, R.L., "Higher Order Three-Dimensional Hybrid-Stress Elements for Thick-Plate Analyses," Intl. J. Numer. Methods Engr., 17, pp 53-69 (1981).

120. Altus, E., Rotem, A., and Shmueli, M., "Free Edge Effect in Angle Ply Laminates - A New Three Dimensional Finite Difference Solution," J. Composite Matls., 14, pp 21-30 (1980).

LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles inlcude technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains an article about vortex shedding from cylinders and the resulting unsteady forces and flow phenomena.

Ms. S.T. Fleischmann and Professor D.W. Sallet of the University of Maryland, College Park, Maryland have written the second part of a two-part paper that presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part II introduces vortex shedding from non-circular cylinders and the topic of cylinders undergoing flow-induced vibration.

VORTEX SHEDDING FROM CYLINDERS AND THE RESULTING UNSTEADY FORCES AND FLOW PHENOMENA PART II

S.T. Fleischmann and D.W. Sallet*

Abstract. This two-part paper presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part II introduces vortex shedding from non-circular cylinders and the topic of cylinders undergoing flow-induced vibration. Experimental values of the unsteady lift and drag coefficients and experimental values of the Strouhal number for circular cylinders over a wide range of Reynolds numbers obtained from numerous investigators are presented.

VORTEX SHEDDING FROM NON-CIRCULAR CYLINDERS

The preceding section treated only vortex shedding from circular cylinders. Most measurements have been made using circular cylinders, but considerable data for cylinders of non-circular cross section (that is, of other basic shapes used in structures) also exist. Attempts have been made to correlate data from other shapes with that from circular cylinders through the development of a universal Strouhal number. So that it will be applicable to all bluff bodies from which vortex shedding occurs, this universal Strouhal number is based on wake parameters rather than free-stream velocity and cylinder dimensions. Various studies of vortex shedding from cylinders of non-circular cross sections are considered and the universal Strouhal number developed by three investigators are discussed below.

Knauss, John, and Marks [51] studied vortex shedding from elliptical cylinders having small eccentricity and from square cylinders at various angles of attack in the low Reynolds number range ($300 \leq Re \leq 1200$). It should be noted that the results from elliptical cylinders should correspond most closely with those of circular cylinders because, as Knauss noted, the absence of a sharp edge allows the separation line to vary. For cylinders with sharp edges separation usually occurs along those edges. It was found [51] that, for elliptical cylinders with an eccentricity between 0.6 and 0.8 at zero angle of incidence, the data for $Re \leq 500$ are well represented by Roshko's relation for circular cylinders: $F = 0.212\,(Re) - 2.7$. Above $Re = 500$, the best fit equation was a power law relationship $F = 0.27\,(Re_{do})^{0.98}$ similar to Roshko's relation. For square cylinders there is a sudden drop in the Strouhal number as the angle of incidence increases beyond about 30° for various Reynolds numbers; this drop has been attributed to a detachment of the flow from the cylinder [51]. Huthloff [52] recently presented extensive measurements of the Strouhal number and the alternating lift coefficient for various cross sections, including circular cross sections, in the Reynolds numbers range of 10^4 to 10^5. For non-circular cylinders he gave the lift coefficient and the Strouhal number as a function of angle of attack for various Reynolds numbers. He found that cylinders having square, rectangular, semicircular, or hexagonal cross sections experienced periodic forces that are considerably higher than those of circular cylinders. This is perhaps not surprising because all of the non-circular cylinders had sharp edges that would tend to define the separation line and therefore correlate the flow along the span of the cylinder. Highly correlated flow would then result in higher periodic forces. Representative results for C_L presented by Hothloff [52] are shown in Figure 11.

Lee [53] studied the effect of free-stream turbulence on vortex shedding and drag on square cylinders. He also presented a study of the effects of varying

*Department of Mechanical Engineering, The University of Maryland, College Park, MD 20742.

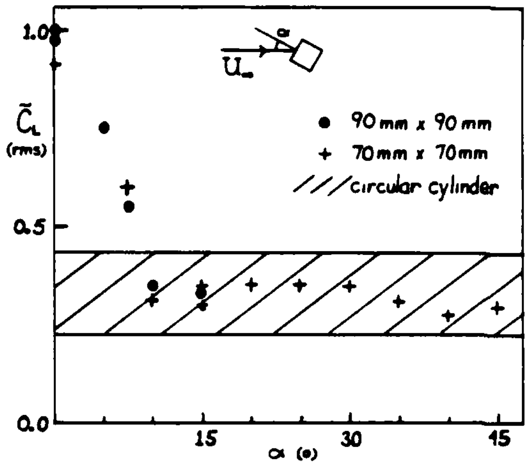

Figure 11. Representative Results [52] Showing Increased Lift Coefficient for Square Cylinders at Small Angles of Attack as Compared to Similar Results for Circular Cylinders ($4.2 \times 10^4 < Re < 1.8 \times 10^5$).

the angle of attack of square cylinders that included careful measurements of the pressure distribution on the faces of the square made with multiple, equally-spaced pressure sensors. Rockwell [32] also studied vortex shedding from square cylinders at various angles of attack and found that the low frequency modulation of the lift coefficient was due to unstable reattachment of the flow near the end of the cylinder wall.

Twigg-Molecey and Baines [54] measured the Strouhal number as a function of Reynolds number for triangular cylinders in the range $9 \times 10^3 < Re < 4 \times 10^4$. They used pressure measurements on the cylinder face to obtain the periodic coefficients of lift and moment. These studies are presented as typical examples and to illustrate the general problem of vortex shedding from non-circular cylinders. The papers by Knauss [51] and Huthloff [52] contain numerous references to other work in this area.

In all of the studies mentioned (with the exception of the elliptical cross section at low Reynolds numbers) the S = S(Re) relationship was found to be different from that for circular cylinders. Figure 12, which shows Roshko's data for a circular cylinder, a

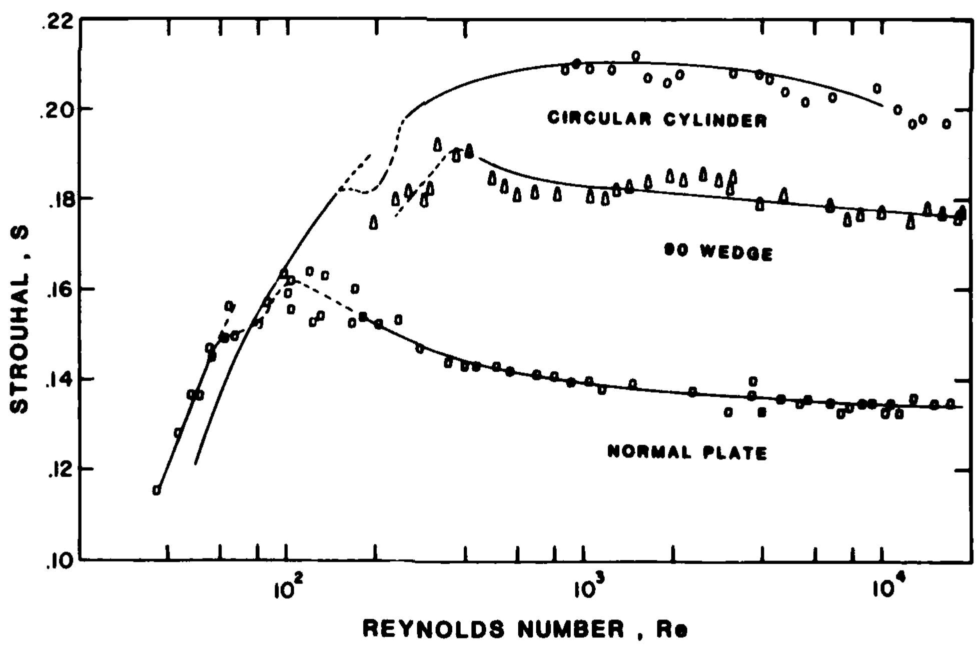

Figure 12. Roshko's Measurement of S = S(Re) for Various Geometries [55].

90° wedge, and a flat plate illustrates this point. One way to correlate all of the bluff body data is to base the Strouhal number and the Reynolds number on wake parameters rather than on cylinder and upstream flow parameters. It is expected that such a Strouhal number will be universal; that is, it will apply to all bluff bodies.

In 1953, Roshko [55] found that his data for cylinders, flat plates, and 90° wedges were well correlated if they were presented using a wake Strouhal number and a wake Reynolds number. The characteristic length used in each of these numbers was h', the separation distance of the shear layers when they become parallel. This distance was calculated using notched hodograph theory. The free stream velocity U_∞ was not used; rather, the velocity at the point of separation U_b was used where U_b was found using Bernoulli's equation and the measured base pressure coefficient C_{bp}.

$$\frac{U_b}{U_\infty} = (1 - C_{bp})^{1/2}$$

Roshko's wake Strouhal number is

$$S^* = \frac{fh'}{U_b} = S\,\frac{U_\infty}{U_b}\,\frac{h'}{d}$$

and his wake Reynolds number is

$$Re^* = \frac{U_b h'}{\nu} = Re\,\frac{h' U_b}{d\,U_\infty}$$

where d is the cylinder dimension and Re and S are the usual Reynolds number and Strouhal number based on free-stream velocity and cylinder dimensions. Roshko's results using the wake parameters discussed are shown in Figure 13; the good correlation is evident.

Bearman [56] later noted that Roshko's formulation assumes that the vortices form from shear layers at the spacing predicted by notched hodograph theory. He further noted that, in such cases as near-wake interference, the commencement of vortex shedding is delayed to a point downstream of the cylinder and that the separation of the shear layers

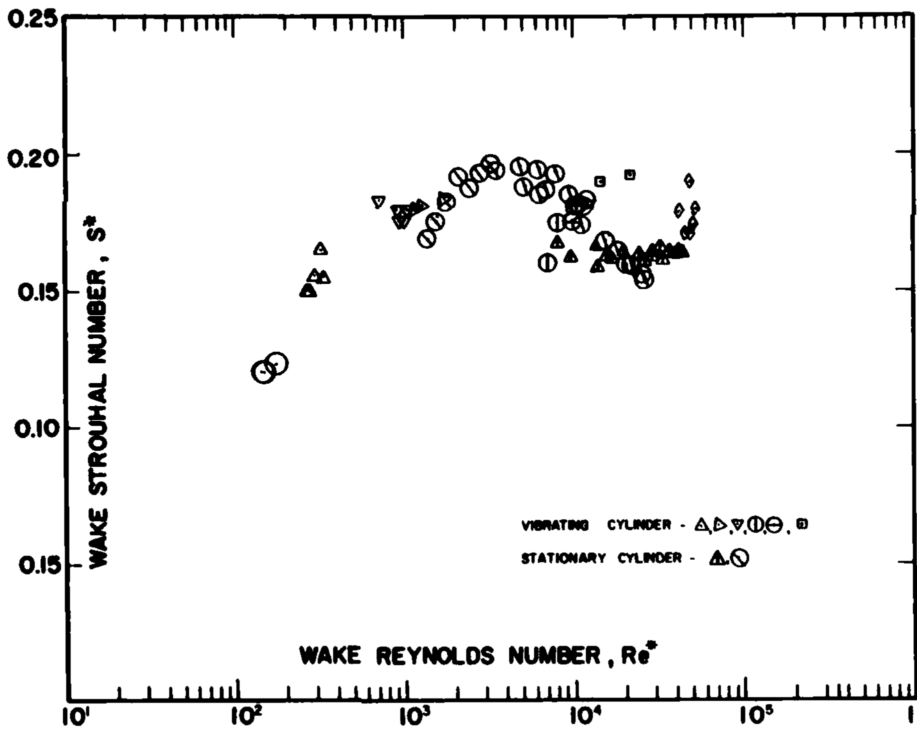

Figure 13. Wake Strouhal Number vs. Wake Reynolds Number. For stationary cylinders [54]: Δ, triangular cross section-Roshko; ⦸, circular cylinder-Roshko; for vibrating cylinders [56]: Δ, Griffin and Ramberg-1974; ▷, Griffin et al-1973; ∇, Griffin and Ramberg-1976; ⦶, Tanida et al-1973; ⊖, Stansby-1976; ⊡, Meyers-1975; ⊙, Tanida et al-1973.

at that point is not equal to the shear layer separation obtained from notched hodograph theory. Bearman then defined a new universal Strouhal number based on the distance h" between the shear layer at the commencement of vortex shedding. This distance h" is equal to the lateral spacing h in the vortex street. Bearman's universal Strouhal number is defined as:

$$S_B = \frac{fh}{U_b} = \frac{S\,h}{d}\frac{U_\infty}{U_b}$$

The ratio $\frac{h}{d}$ can be found using the stability criterion proposed by either von Karman ($h/\ell = .281$) or Kronauer

$$\left.\frac{\partial C_D}{\partial (h/\ell)}\right|_{\frac{U_S}{U_\infty}} = 0$$

C_D is Karman's analytical expression. Bearman found the best correlation by using the Kronauer stability criterion to determine $\frac{h}{\ell}$; the shedding frequency and base pressure coefficient were experimentally obtained.

Both Roshko's and Bearman's formulations apply to stationary cylinders. Griffin [57] recently extended the concept of the universal Strouhal number to the case of freely vibrating cylinders. In his formulation the length parameter h' was the measured distance between the shear layers at the end of the vortex formation region. His results using his own data and the data of other investigators are given in Figure 13; there is good agreement with results for stationary cylinders of various cross sections.

VIBRATING CYLINDERS

The periodic forces due to vortex shedding from a cylinder in cross flow and the various flow regimes for a rigidly supported circular cylinder – that is, a cylinder for which the flow-cylinder interaction is restrained – have been described. The question now arises: what happens when flow-cylinder interaction is allowed and the cylinder vibrates. The question is relevant to all disciplines of engineering because costly structural damage can occur due to vortex-induced resonant motions of elastically-supported structural members; more knowledge in this area is needed.

Berger and Willie [37] reviewed the work in vibrating cylinders up to 1972 and Mair and Maull [40] reported on results presented at Euromech 17. Brief introductory reviews of more recent work are available [58, 59]. A scheme for the classification and analysis of flow-induced vibration problems has been given [60]. Numerous conferences concerning flow-induced vibrations in the past 10 years attest to the continued research interest in this problem [61-65]. This section considers flow-induced cylinder vibration; emphasis is on the physical processes involved.

It should be noted that the flow-cylinder interaction is extremely complex and highly nonlinear. The motion of the cylinder changes the geometry of the vortex wake and the periodic fluid forces on the cylinder. In turn, the changes in the periodic forces change the cylinder motion. Because the flow-cylinder interaction is so complex, results obtained from experiments in which the frequency and amplitude of vibration are externally controlled are often applied to the case of flow-induced vibration. Such applications must be done very carefully. Griffin [66] has shown that the near wake and the phase relation between the flow field and the cylinder motion are essentially the same for cylinders under forced and flow-induced vibrations if the Reynold's number and the frequency and amplitude of vibration are matched.

For small amplitude vibrations increased span-wise correlation in flow has been reported [24, 37, 67]. The increased span-wise correlation makes the flow more strongly two-dimensional and therefore increases the lift force on the cylinder. In experiments on forced vibrating cylinders Griffin and Ramberg [30] noted that when the ratio of vibration amplitude to cylinder diameter, a/d, is less than 50% (within the range of observed resonant response to flow-induced vibrations) the circulation of the vortices increases and the length of formation decreases. Bearman [56] found a nearly inverse relation between the base pressure coefficient (and therefore the drag) and the length of formation. Increased steady drag for a vibrating cylinder has been observed.

When the vortex shedding frequency is sufficiently close to the natural frequency of an elastically mounted cylinder or structural member, the vortex

shedding frequency, f, and the natural frequency become synchronized; that is, the Strouhal frequency, f_s, is suppressed and for a range of Reynold's numbers the shedding frequency is equal to the natural frequency of the cylinder system. This phenomenon is known as lock-in or wake capture. It is under conditions of lock-in that large amplitude resonant vibrations are observed.

Umemura, Yamaguchi, and Shiraki [68] used a spring mounted circular cylinder to investigate the amplitude response and the limits of lock-in as a function of external damping. They presented the amplitude response and the frequency of vortex shedding for the same cylinder under three different conditions of damping. For the highly damped system they found that almost no lock-in occurred. When damping was decreased by about an order of magnitude, lock-in occurred when the Strouhal frequency reached the system's natural frequency and persisted over a short range of higher Reynold's numbers, after which the shedding frequency abruptly returned to the Strouhal frequency. When the damping was decreased by yet another order of magnitude, lock-in occurred over the entire range of Reynold's numbers tested, both below and above V^*, the free-stream velocity for which the Strouhal and natural frequencies are equal. The maximum amplitude of vibration increased by roughly an order of magnitude each time the damping was decreased by about an order of magnitude. Furthermore the flow speed at which the maximum amplitude occurred increased with decreased external damping.

Although the flow speed, V_{max}, for which the maximum amplitude occurred was different for the three cases quoted, and the maximum amplitude was different, the flow speed range over which pronounced resonant vibration occurred relative to V_{max} seemed to be about the same (± 1m/sec) in all cases. For cases of high and medium damping the vibration built up and died down outside the region of lock-in, but the maximum amplitude of vibration occurred in the region of lock-in.

Feng and Parkinson [69], in experiments with spring mounted cylinders of circular and D-section, observed similar behavior in their investigation of lock-in for the case of the circular cylinder. They also found that the free-stream velocity for which the maximum amplitude was attained was lower when the velocity was gradually decreased than when it was gradually increased through the lock-in region. Feng and Parkinson [69] also observed that, while lock-in occurred mostly above V^* for circular cylinders, it occurred mostly below V^* for the D-section cylinders.

All cylinders experience fluid damping in addition to external mechanical damping. Griffin and Koopmann [59] reported a rapid decrease in fluid damping just before lock-in and a rapid increase immediately thereafter. Skop, Ramberg, and Ferer [70] have discussed the measurement and evaluation of fluid damping and added mass.

The amplitude and frequency response of spring mounted and externally damped cylinders that were free to vibrate perpendicular to the flow direction in water have been studied by Meier-Windhorst [71]. Similar results for spring mounted cylinders in air have been obtained by Glass [72] and others [58, 59]. Toebes and Eagleston [73] showed experimentally that the amplitude response of non-circular bluff bodies depends in general on the trailing edge geometry.

Throughout the lock-in region (with the exception of possibly one point) the shedding frequency is different from the Strouhal frequency observed for stationary cylinders. Because the shedding frequency is different, the longitudinal spacing of the wake vortices will also be different from that in the wake of stationary cylinders. In an extension of the two-dimensional Karman model to cylinders under small amplitude vibrations Sallet [14] noted that, for constant lateral spacing, an increase in longitudinal spacing leads to an increase in lift and vice versa. The Karman model also shows that, at constant longitudinal spacing (shedding frequency), changes in lateral spacing change the lift. In observations of cylinders under forced vibration Griffin and Ramberg [30] confirmed earlier observations [28] that, at constant vibration frequency, an increase in cylinder amplitude results in a decrease in lateral vortex spacing and that, at constant amplitude, the longitudinal spacing varies inversely with vibration frequency. The lateral spacing for a cylinder forced to vibrate at 85% of the Strouhal frequency approached zero as a/d approached 0.5 [30]. Further increases in the amplitude caused serious distortions of the wake. For vibration frequencies closer to the Strou-

hal frequency the critical vibration amplitude for which serious disorders in the wake first appeared also increased. It is possible that the approach to zero lateral spacing poses a limit to the amplitude of flow-induced vibration.

In accord with the observed resonant amplitude response of an elastically-supported cylinder under conditions of lock-in, Griffin and Koopmann [59] showed that the coefficient of lift increases to a maximum of $C_L^* = 0.5$ to 0.6 and then gradually decreases as the Reynolds number is slowly increased through the region of lock-in. Bishop and Hassan [74] showed that C_L^* for a vibrating cylinder is greater than C_L for a stationary cylinder before the maximum amplitude is reached and that C_L^* was less than C_L afterward.

Griffin, Skop, and Koopmann [58] noted that the energy transfer from the fluid to the cylinder is positive when the lift force has a component in phase with the cylinder motion. They used measurements to show that maximum energy transfer occurs when the maximum amplitude is obtained. It has been reported [58, 59, 74, 75] that a phase shift of about 90° occurs as the lock-in region is traversed; i.e., a phase shift of cylinder motion relative to the lift force.

The amplitude response of a cylinder in cross flow is evidently complex. The most successful model of cylinder motion has been the wake oscillator model, which was introduced by Hartlan and Currie [76] and further developed by Skop and Griffin [77]. An introduction to the model and further references are available [2, 3, 58, 59].

The focus of this paper has been the periodic forces on a cylinder in cross flow. Not only do the periodic forces due to cylinder vibration change but the steady drag force is also increased. Sallet [14] in his extension of the Karman model to vibrating cylinders noted a general trend to increased steady drag as cylinder amplitude increases. Tanida, Okajima, and Watanabe [78] have measured the increased drag experienced by a forced vibrating circular cylinder that was towed through water. Griffin, Skop, and Koopmann [58] measured an increased steady drag for freely vibrating cylinders. Griffin and Ramberg [30] found an inverse relation between the length of formation and the steady drag and reported increased steady drag when the cylinder vibrates. Additional information is available [3].

Both the periodic forces and the steady forces change radically as a cylinder vibrates; flow-cylinder interaction is extremely complex. The topic of flow-induced vibrations is a topic of current research and much work remains in this area.

ACKNOWLEDGMENT

The authors wish to acknowledge the Minta Martin committee at the University of Maryland for their support during the writing of this paper and for their continuing support of further research in this area.

REFERENCES

1. Chen, S.S., "Flow-induced Vibrations of Circular Cylindrical Structures. Part I: Stationary Fluids and Parallel Flow," Shock Vib. Dig., 9 (10), pp 25-38 (Oct 1977).

2. Chen, S.S., "Flow-induced Vibrations of Circular Cylindrical Structures. Part II: Cross-flow Considerations," Shock Vib. Dig., 9 (11), pp 21-27 (Nov 1977).

3. Blevins, R.D., Flow-induced Vibration, Von Nostrand Reinhold (1977).

4. Rubach, H.L., "Ueber die Entstehung und Fortbewegung des Wirbelpaares hinter zylinderischen Körpern," Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Verein Deutscher Ingenieure, Heft 185, Berlin (1916).

5. Foppl, L., "Wirbelbewegung hinter einem Kreiszylinder," Sitzungsberichte der mathematisch-physikalischen Klasse der Köninglich Bayerischen Akademie der Wissenschaften, München, pp 1-17 (1913).

6. Strouhal, V., "Über Eine Besondere Art der Tonnerregung," Ann. Phys. Chemie, Neue Folge, Bd. 5, Heft 10, pp 216-251 (Oct 1878).

7. von Karman, T. and Rubach, H., "Über den Mechanismus des Flüssigkeits und Luftwider-

standes," Physikalische Zeitschrift, 13 (2), pp 49-59 (Jan 1912).

8. Bernard, H., "Formation de Centres de Giration à l'arrière d'un Obstacle en Mouvement," Comp. Rend., Acad. Sci. (Paris), 147, pp 839-842 (Nov 9, 1908).

9. von Kármán, T., "Über den Mechanismus des Widerstandes den ein bewegter Körper in einer Flüssigkeit erfährt," Nachrichten der K. Gesellschaft der Wissenschaften zu Göttingen; Mathematisch-Physikalische Klasse, pp 509-517 (1911).

10. Ibid., pp 547-556 (1912).

11. Krzywoblocki, M.Z., "Vortex Streets in Fluids," Applied Mechanics Surveys, edited by H. Horman Abramson, Harold Leibowitz et. al., Spartan Books, pp 885-892 (1966).

12. Sallet, D.W., "On the Prediction of Flutter Forces," Contribution to Flow-Induced Structural Vibrations, E. Naudascher, editor (Symp., Karlsruhe, Germany, Aug 1972) Springer Verlag, pp 159-176.

13. Sallet, D.W., "The Lift Force due to von Kármán's Vortex Wake," J. Hydronautics, 7 (4), pp 161-165 (Oct 1973).

14. Sallet, D., "The Drag and Oscillating Transverse Force on Vibrating Cylinders due to Steady Fluid Flow," Ing. Arch., 44, pp 113-122 (1975).

15. Sallet, D., "On the Spacing of Kármán Vortices," J. Appl. Mechanics, Trans. ASME, pp 370-372 (June 1969).

16. Bearman, P.W., "On Vortex Street Wakes," J. Fluid Mechanics, 28, pt 4, pp 625-641 (1967).

17. Griffin, O., "On Vortex Strength and Drag in Bluff-Body Wakes," J. Fluid Mechanics, 69, pt 4, pp 721-728 (1975).

18. Jendrzejczyk, J.A. and Chen, S.S., "Fluid Forces Acting on Circular Cylinders in Liquid Crossflow," Tech. Mem. ANL-CT-81-13, Argonne Nat'l Lab. (Dec 1980).

19. Keefe, R.T., "Investigation of the Fluctuating Forces Acting on a Circular Cylinder in a Subsonic Stream and the Associated Sound Field," J. Acoust. Soc. Amer., 34 (11), pp 1711-1714 (Nov 1962).

20. Okamoto, T. and Yagita, M., "The Experimental Investigation on the Flow Past a Circular Cylinder of Finite Length Placed Normal to the Plane Surface in a Uniform Stream," Bull. JSME, 16 (95), pp 805-814 (May 1973).

21. Humphreys, J.S., "On a Circular Cylinder in a Steady Wind at Transition Reynolds Numbers," J. Fluid Mechanics, 9, pt 4, pp 603-612 (1960).

22. Hussain, AKMF and Ramjee, V., "Periodic Wake Behind a Circular Cylinder at Low Reynolds Numbers," Aeronaut. Quart., 27, pt 2, pp 123-142 (May 1976).

23. Schubauer, G.B. and Skramstad, H.K., "Laminar Boundary-Layer Oscillations and Transition on a Flat Plate," NACA Rep. 909 (1943).

24. Toeves, G.H., "The Unsteady Flow and Wake Near an Oscillating Cylinder," J. Basic Engr., pp 493-505 (Sept 1969).

25. Griffin, O.M., "Flow near Self-Excited and Forced Vibrating Cylinders," J. Engr. Indus., Trans. ASME, pp 539-547 (May 1972).

26. Gaster, M., "Vortex Shedding from Slender Cones," J. Fluid Mechanics, 38, pt 3, pp 565-576 (1969).

27. Umemura, S., Yamaguchi, T., and Shirahi, K., "On the Vibration of Cylinders Caused by Karman Vortex," Bull. JSME, 14 (75), pp 929-937 (1971).

28. Koopmann, G.H., "The Vortex Wakes of Vibrating Cylinders at Low Reynolds Numbers," J. Fluid Mechanics, 28, pp 501-512 (1967).

29. Griffin, O.M. and Votaw, C.W., "The Vortex Street in the Wake of a Vibrating Cylinder," J. Fluid Mechanics, 55, pp 31-48 (1972).

30. Griffin, O.M. and Ramberg, S.E., "The Vortex Street Wakes of Vibrating Cylinders," J. Fluid Mechanics, 66, pt 3, pp 553-576 (1974).

31. Thomas, D.G. and Kraus, K.A., "Interaction of Vortex Streets," J. Appl. Physics, 35 (12), pp 3458-3459 (Dec 1964).

32. Rockwell, D.O., "Organized Fluctuations due to Flow Past a Square Cross-Section Cylinder," J. Fluids Engr., Trans. ASME, 99 (3), pp 511-516 (Sept 1977).

33. Roshko, A., "On the Development of Turbulent Wakes from Vortex Streets," NACA Tech. Note 2913 (Mar 1953).

34. Nishioha, M. and Sato, H., "Mechanism of Determination of the Shedding Frequency of Vortices behind a Cylinder at Low Reynolds Numbers," J. Fluid Mechanics, 89, pt 1, pp 49-60.

35. Goldstein, S. (Ed), Modern Developments in Fluid Mechanics, vol. II, Dover Publ. (1965).

36. Tritton, D.J., "Experiments on the Flow Past a Circular Cylinder at Low Reynolds Numbers," J. Fluid Mechanics, 6, pt 4, pp 547-560.

37. Berger, E. and Wille, R., "Periodic Flow Phenomena," Ann. Rev. Fluid Mechanics, 4, pp 313-340 (1972).

38. Marrow, T.B. and Kline, S.J., "The Evaluation and Use of Hot-wire and Hot Film Anemometers in Liquids," Stanford Univ. Rep. MD-25 (1971).

39. Kohan, S. and Schwarz, W.H., "Low Speed Calibration Formula for Vortex Shedding from Cylinders," Physics Fluids, 16, pp 1528-1529 (1973).

40. Mair, W.A. and Maull, D.J., "Bluff Bodies and Vortex Shedding - a Report on Euromech 17," J. Fluid Mechanics, 45, pt 2, pp 209-224 (1971).

41. Tritton, D.J., "A Note on Vortex Streets behind Circular Cylinders at Low Reynolds Numbers," J. Fluid Mechanics, 45, pt 1, pp 203-208 (1971).

42. Taneda, S., "Experimental Investigation of the Wakes behind Cylinders and Plates at Low Reynolds Numbers," J. Phys. Soc. Japan, 11, p 1284 (1956).

43. Gerrard, J.H., "The Mechanics of the Formation Region of Vortices behind Bluff Bodies," J. Fluid Mechanics, 25, pt 2, pp 401-413.

44. Jaminet, J.F. and Van Atta, C.W., "Experiments on Vortex Shedding from Rotating Circular Cylinders," AIAA J., 7 (9), pp 1817-1819.

45. Schiller, L. and Linke, W., "Druck-und Reibungswiderstand des Zylinders bei Reynoldsschen Zahlen 5000 bis 40000," Z.F.M., Jahrg. 24, Nr. 7, pp 193-198 (Apr 13, 1933) (in English-NACA TM 715).

46. Bearman, P.W., "On Vortex Shedding from a Circular Cylinder in the Critical Reynolds Number Regime," J. Fluid Mechanics, 3, pt 3, pp 577-585.

47. Jones, G.W., Cincotta, J.J., and Walker, R.W., "Aerodynamic Forces on Stationary and Oscillating Circular Cylinders at High Reynolds Numbers," NASA TR R-300 (Feb 1969).

48. Schmitt, L.V., "Measurements of Fluctuating Air Loads on a Circular Cylinder," J. Aircraft, 2 (1), pp 49-55 (Jan/Feb 1965).

49. Schlinker, R.H., Fink, M.R., and Amiet, R.K., "Vortex Noise from Non-Rotating Cylinders and Airfoils," AIAA Paper 76-81 (Jan 1976).

50. Roshko, A., "Experiments on the Flow Past a Circular Cylinder at Very High Reynolds Number," J. Fluid Mechanics, 10, pp 345-356.

51. Knauss, D.T., John, J.E.A., and Marks, C.H., "The Vortex Frequencies of Bluff Cylinders at Low Reynolds Numbers," J. Hydronautics, 10 (4), pp 121-126 (Oct 1976).

52. Huthloff, E., "Windkanaluntersurhungen zur Bestimmung der periodischen Kräjte bei der Umströmung schlanker scharfkantiger Köroper," Stahlbau, 44 (4), pp 97-103 (Apr 1975).

53. Lee, B.E., "The Effect of Turbulence on the Surface Pressure Field of a Square Prism," J. Fluid Mechanics, 69, pt 2, pp 263-282.

54. Twigge-Molecey, C.F.M. and Baines, W.D., "Aerodynamic Forces on a Triangular Cylin-

der," ASCE J. Engr. Mechanics Div., 99 (EM 4), pp 803-818 (Aug 1973).

55. Roshko, A., "On the Drag and Shedding Frequency of Two-Dimensional Bluff Bodies," NACA TN 3169 (July 1954).

56. Bearman, P.W., "On Vortex Street Wakes," J. Fluid Mechanics, 28, pt 4, pp 625-641.

57. Griffin, O.M., "Universal Strouhal Number for the 'Locking-on' of Vortex Shedding to the Vibrations of Bluff Cylinders," J. Fluid Mechanics, 85, pt. 3, pp 591-606 (Apr 1978).

58. Griffin, O.M., Skop, R.A., and Koopmann, G.H., "The Vortex Excited Resonant Vibrations of Circular Cylinders," J. Sound Vib., 31 (2), pp 235-249 (1973).

59. Griffin, O.M. and Koopmann, G.H., "The Vortex Excited Lift and Reaction Forces on Resonantly Vibrating Cylinders," J. Sound Vib., 54 (3), pp 435-448 (1977).

60. Naudascher, E. and Rockwell, D., "Oscillator Model Approach to the Identification and Assessment of Flow-Induced Vibrations in a System," J. Hydraul. Res., 18 (1), pp 59-82 (1980).

61. Proc. IUTAM-IAHR Symp. Flow-Induced Struct. Vib., Karlsruhe, Germany (1972).

62. Sallet, D.W., "Symposium on Practical Experiences with Flow-Induced Vibrations," Karlsruhe, Germany (Sept 3-6, 1979), Shock Vib. Dig., 12 (1), pp 36-40 (Jan 1980).

63. Proc. Flow-Induced Vibrations Symp., 3rd Natl. Congress Pressure Vessel Piping Tech., San Francisco, Cal., June 25-29, 1979, publ. by ASME (1979).

64. E Naudascher (ed), Flow-Induced Structural Vibrations, Springer-Verlag (1974).

65. Eaton, K.J., (ed), Proc. the 4th Intl. Conf. Wind Effects Bldgs. Struct., Heathrow (1975), Cambridge Univ. Press.

66. Griffin, O.M., "Flow near Self-Excited and Forced Vibrating Circular Cylinders," J. Engr. Indus., Trans. ASME, 94, pp 539-547 (May 1972).

67. Dale, J.R. and Holler, R.A., "Vortex Wakes from Flexible Circular Cylinders at Low Reynolds Numbers," 1-225 974, copy 1, U.S. Naval Air Dev. Center, Johnsville, Warminster, PA.

68. Umemura, S., Yamaguchi, T., and Shiraki, K., "On the Vibration of Cylinders Caused by Karman Vortex," Bull. JSME, 14 (75), pp 929-937 (1971).

69. Feng, C.C. and Parkinson, G.V., paper given at Euromech 17 (1970).

70. Skop, R.A., Ramberg, S.E., and Ferer, K.E., "Added Mass and Damping Forces on Circular Cylinders," NRL Report 7970 (Mar 19, 1976).

71. Meier-Windhorst, A., "Flatterschwingungen von Zylindern im gleichmässigen Flüssigkeitsstrom," Mitteilungen des Hydraulischen Instituts der Technischen Hochschule München, Heft 9, pp 1-29 (1939).

72. Glass, R., "A Study of the Self-Excited Vibrations of Spring Supported Cylinders in a Steady Fluid Stream," Doctoral Thesis, Univ. Maryland (1966).

73. Toebes, G.H. and Eagleston, P.S., "Hydroelastic Vibrations of Flat Plates Related to Trailing Edge Geometry," J. Basic Engr., Trans. ASME, pp 671-678 (Dec 1961).

74. Bishop, R.E.D. and Hassan, A.Y., "The Lift and Drag Forces on a Circular Cylinder Oscillating in a Flowing Fluid," Proc. Royal Soc. (London), Ser. A, 277, pp 51-75 (1964).

75. Diana, G. and Falco, M., "On the Forces Transmitted to a Vibrating Cylinder by a Blowing Fluid," Meccanica, 6, pp 9-22 (1971).

76. Hartlan, R. and Currie, I., "A Lift-Oscillator Model for Vortex Induced Vibrations," ASCE J. Engr. Mechanics Div., 96, pp 571-591 (1970).

77. Skop, R.A. and Griffin, O.M., "A Model for the Vortex-Excited Resonant Vibrations of Bluff Bodies," J. Sound Vib., 27, pp 225-233 (1973).

78. Tanida, Y., Okajima, A., and Watanabe, Y., "Stability of a Circular Cylinder Oscillating in Uniform Flow or in a Wake," J. Fluid Mechanics, 61, pt 4, pp 769-784.

79. Kovaznay, L.G.S., "Hot-Wire Investigation of the Wake Behind Cylinders at Low Reynolds Numbers," Proc. Royal Soc., (London) Ser. A, 198 (1053), pp 174-190 (1949).

80. Hanson, A.R., "Vortex Shedding from Yawed Cylinders," AIAA J., 4 (4), pp 738-740.

81. Lugt, H.J. and Haussling, H.J., "Laminar Flows Past a Flat Plate at Various Angles of Attack," Lecture Notes (no. 8) in Physics, Springer-Verlag (1971).

82. Jordan, S.K. and Fromm, J.E., "Oscillating Drag Lift and Torque on a Circular Cylinder in a Uniform Flow," Physics Fluids, 15 (3), pp 371-376 (Mar 1972).

83. McGregor, O.M., "An Experimental Investigation of the Oscillating Pressures on a Circular Cylinder in a Fluid Stream," UTIA. Tech. Note No. 14 (June 1957).

84. Gerrard, J.H., "An Experimental Investigation of the Oscillating Lift and Drag of a Circular Cylinder Shedding Turbulent Vortices," J. Sound Vib., pp 244-256.

85. Relf, E.F. and Simmons, L.F.G., "The Frequency of the Eddies Generated by the Motion of Circular Cylinders through a Fluid," Aeronaut. Res. Comm. (London), R and M, no. 917 (June 1924).

86. Drescher, H., "Messung der auf Querangeströmte Zylinder Ausgeubten Zeitlich Veränderten Drücke," Z. Flugwiss, 4, Heft 1/2, p 17 (1956).

87. Delany, M.K. and Sorenson, M.E., "Low Speed Drag of Cylinders of Various Shapes," NACA TN 3038 (1953).

88. Warren, W.F., "An Experimental Investigation of Fluid Forces of an Oscillating Cylinder," Ph.D. Thesis, Univ. Maryland (1962).

89. Kuwahara, K., "Study of Flow Past a Circular Cylinder by an Inviscid Model," J. Phys. Soc. Japan, 45 (1), pp 292-297 (July 1978).

90. Takao, Y., IBM Japan Sci. Ctr., Rep. G318-1909-0 (1973).

91. Fung, Y.C., "Fluctuating Lift and Drag Acting on a Cylinder in a Flow at Supercritical Reynolds Numbers," J. Aerospace Sci., 27 (11), pp 801-814 (Nov 1960).

92. Schmidt, L.V., "Measurements of Fluctuating Air Loads on a Circular Cylinder," J. Aircraft, 2 (1), pp 49-55 (Jan/Feb 1965).

93. Schlichting, H., Boundary Layer Theory (6th ed), McGraw-Hill, p 17, fig. 1.4.

ANNUAL ARTICLE INDEX

FEATURE ARTICLES

LITERATURE REVIEWS

	ISSUE	PAGES
Huseyin, K. **Vibrations and Stability of Mechanical Systems: II**	1	21-29
Nakra, B.C. **Vibration Control with Viscoelastic Materials - II**	1	17-20
Etter, P.C. **Underwater Acoustic Modeling Techniques**	2	11-20
Massoud, M. **Impedance Methods for Machine Analysis**	3	17-21
Roberts, J.B. **Response of Nonlinear Mechanical Systems to Random Excitation. Part I: Markov Methods**	4	17-28
Roberts, J.B. **Response of Nonlinear Mechanical Systems to Random Excitation. Part 2: Equivalent Linearization and Other Methods**	5	15-29
Chang, C.H. **Vibrations of Conical Shells**	6	9-17
Waberski, A. **Method of R-Functions and Its Application to Analysis of Vibrations of Plates and Other Structures**	7	11-14
Leis, B.N. and Broek, D. **The Role of Similitude in Fatigue and Fatigue Crack Growth Analyses**	8	15-28
Ibrahim, R.A. **Parametric Vibration. Part VI: Stochastic Problems (2)**	9	23-35
Leissa, A.W. **Plate Vibration Research, 1976 - 1980: Classical Theory**	9	11-22
Leissa, A.W. **Plate Vibration Research, 1976 - 1980: Complicating Effects**	10	19-36
Fleischmann, S.T. and Sallet, D.W. **Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomenon. Part I**	11	9-22
Fleischmann, S.T. and Sallet, D.W. **Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomenon. Part II**	12	15-24

BOOK REVIEWS

STATISTICAL ENERGY ANALYSIS OF DYNAMIC SYSTEMS

R.H. Lyons
MIT Press, Cambridge, MA

Large and lightweight aircraft and other structures, including houses have focused interest on higher modal analysis for predicting structural fatigue, equipment failure, and noise production. Traditional analyses of mechanical system vibration of machines and structures were concerned with lower resonant modes. Statistical energy analysis (SEA), which is expressed in terms of random parameters, is now being utilized by mechanical and structural engineers.

The prime advantage of SEA is that a large number of modes can be compressed into a few coherent features of the modal pattern (direct field and a few early reflections), and the incoherent pattern (reverberent field) can be compressed into a few frequency bands. In addition, SEA allows for a simple description of a system; modes or waves are used to describe the field.

The 15 chapters of the book are contained in two parts; the numerous references are annotated.

Part I on basic theory consists of four chapters. The history and development of SEA, and single- and multi-degree-of-freedom systems are described. The storage of kinetic and potential energy by modes in free and forced vibration plus the decay or rate of energy removed by damping are considered.

Chapter III introduces the concept of average power flow – average in both ensemble and temporal sense between simple single- and more complicated multi-degree of freedom-systems. The idea of blocked systems, similar to that used in electrical systems, is introduced. Power flow in terms of both blocked and coupled system energies are considered; the idea of enlarged modal interactions as a white noise source is presented.

Chapter IV considers the problems of estimating response using average energy distribution. The estimation of displacement and stresses leads to the development of intervals of estimating and confidence coefficients. This is important when statistical analysis of variance shows that the standard deviation is an appreciable fraction of the mean.

Part II centers upon engineering applications of SEA in predicting vibration. Four chapters discuss response estimation during the early stages in the design of a high-speed flight vehicle; dynamic response of a system in terms of stress, acceleration, and pressure; estimations of the average system energy from the SEA model and knowledge of its parameters. The use of such SEA parameters as loss factor, power transfer parameters, and modal density of a system plus the important input power prediction are described. The ratio of the convection speed of pressure waves to the bending wave speed in a turbulent boundary layer is given.

The next three chapters show how the system can be modeled and define subsystems; included are the identification and evaluation of coupling between systems. Parameter evaluation, which is the engineering basis for SEA, is illustrated by measuring damping in both simple and built-up structures, including constraint layer structures.

The author illustrates the evaluation of coupling loss factors by applying them to aerospace structures, acoustical spaces, cylinders, and coupling between structural subsystems. An example is given of the use of SEA in the response estimation of a re-entry vehicle; information on modal density, high-frequency modal coupling loss factors, and the experimental procedures required to determine the parameters are described.

The reviewer has noticed that the most important uses to date have been in noise control problems, noise propagation in ships, and vibrations in nuclear reactors and enclosed space structures. SEA has a major stumbling block: the determination of param-

eters from experimental tests. The reviewer does recommend this book to engineers involved in this subject. However, more work must be done.

H. Saunders
General Electric Co.
Schenectady, NY

DYNAMICS OF MECHANICAL SYSTEMS

J.M. Prentis
Halsted Press, New York, NY
1980, 486 pages, 2nd Edition

This undergraduate text contains material that would typically be found in separate books on machine dynamics, vibrations, and automatic control theory. The entire text would be suitable for a two-semester senior level course; a one semester course could be based on selected chapters. The chapter by chapter contents are as follows:

Chapter 1 - Simple Mechanisms I. This short introductory chapter to the first one-third of the book is devoted to the classification of plane and spatial mechanisms.

Chapter 2 - Simple Mechanisms II. The practical kinematics of planar mechanisms such as cams, gears, gear trains, and linkages are illustrated. The mathematical presentation is based on elementary calculus, without reference to vectors or complex numbers.

Chapter 3 - Force Relationships in Mechanisms I Transmitted Forces and Friction. The first part of this brief chapter considers frictionless mechanisms. The virtual work concept applied to friction is introduced. The chapter concludes with a study of the effects of friction on cams, four-bar, and slider-crank mechanisms.

Chapter 4 - Velocities and Accelerations. The vector kinematic relations for moving spatial reference frames are derived at the beginning of the chapter. The relations are then applied mainly to such planar mechanisms as cams and linkages; the concept of equivalent mechanisms is introduced.

Chapter 5 - Force Relations in Mechanisms II Inertia Forces. This 60-page chapter covers D'Alembert's principle, balancing concepts, gyroscopic effects, angular momentum, plane motion inertia, transmission of inertia forces, and inertial stresses. Analytical and graphical methods are emphasized.

Chapter 6 - I First Order Systems. The automatic control third of the book is introduced with this chapter on lumped parameter modeling. Proportional elements, integrating elements, transfer relations, response, lag, and superposition are described mathematically and physically using differential equations and complex numbers.

Chapter 7 - II Second Order Systems. Chapter 7 is a continuation of the previous chapter. The concepts of amplitude, phase, and frequency are described mathematically and illustrated using spring-mass systems and servo-mechanisms.

Chapter 8 - Automatic Control. This very long chapter deals with the standard topics of open and closed loop systems, derivative control and integral control, position and speed control, stability criteria, Bode diagrams, and system design. The presentation is mainly theoretical; there are illustrations of the application of the theory to practical systems.

Chapter 9 constitutes almost one third of the book. It follows logically the modeling techniques introduced in the chapter on automatic control. The classical spring-mass system, isolation techniques, seismic excitation, and phase plane analysis are considered. Simple multi-degree-of-freedom systems are analyzed. Energy concepts and the Rayleigh method are applied to lumped and distributed systems. Elementary rotor dynamics are also considered.

A section containing practice problems keyed to the chapters follows the last chapter; the answers are given. An index concludes the book.

There is always the danger that a textbook proporting to cover such a wide range of topics will do none of them, or its readers, justice. For the most part the author has successfully avoided this trap. To my personal taste chapters 5 and 9 which deal with dynamics and chapter 8 on automatic control are a bit lean. I would have preferred a stronger treatment and more applications. Another reviewer might say the same about other sections.

Considering the intended usage, and the latitude given the instructor to introduce additional material, the author has produced a reasonable compromise.

The text is well illustrated with clearly marked line drawings. The typeset and organization are pleasing to the eye. The style and exposition are easy to read. Students will probably be pleased with the quantity of well-written descriptive material, which is generally more voluminous than is found in American technical books.

H.J. Sneck
Department of Mechanical Engineering,
Aeronautical Engineering & Mechanics
Rensselaer Polytechnic Institute
Troy, New York

DYNAMICS IN CIVIL ENGINEERING: ANALYSIS AND DESIGN

A. Major
Akadémiai Könyvkiadó, Budapest, Hungary
Vol. I-IV, 1981, 1212 pages, $96.00

Vibration problems caused by time-dependent loads arise in many structures. This comprehensive reference book deals with the theoretical and practical aspects of solving such dynamic problems, which are often very complex. This book is a completely revised and considerably enlarged edition of the internationally known author's 1961 work, Vibration Analysis and Design of Foundations for Machines and Turbines, which is a standard reference book for many engineers.

The extended scope of this second edition includes more detailed treatment of the fundamentals of structural dynamics and their practical applications. To assure conveneint handling of this increased material, the book has been divided into four volumes. The fourth volume is devoted to wind and earthquake effects on tall buildings and various industrial structures and the dynamics of bridges.

The first volume (320 pp) contains a condensed but up-to-date introduction to structural and soil dynamics. In addition, the reader is exposed to the fundamental principles governing the design of machine foundations. The second volume (302 pp) deals with the vibratory characteristics of such machines as hammers and reciprocating engines and with the design of their foundations, including vibration isolation and mechanical methods for mitigating undesirable vibration effects.

The third volume (291 pp), a continuation of the subject matter of volume two, deals with high-speed machinery and steam and nuclear power plants. Again, such general considerations as design criteria are followed by descriptions of various computational methods and useful structural details of machine foundations.

The last volume (306 pp) is devoted mostly to vibrations of tall buildings and industrial structures subjected to wind, earthquake, and blast loads. One chapter deals with the dynamics of hydraulic structures. Finally, the reader is introduced to various types of bridge vibration.

The reviewer believes that the four volumes contain a most comprehensive treatment of dynamic problems in civil engineering from a wide variety of fields. Clear presentation of basic theories is followed by practical applications. In addition, a vast amount of pertinent information is given in tables and graphs; such information is not otherwise easily available to the practicing engineer. Application of the various computational methods are illustrated by numerical examples, and the work of the designer is facilitated by numerous figures showing structural details. The author also provides an extensive bibliography, citing 1377 references. The book is well produced, edited, and indexed. The reviewer believes that these volumes represent a significant contribution to the literature of structural dynamics and will become a standard reference book for anyone interested in the dynamic analysis and design of structures.

R. Szilard
University of Dortmund
August-Schmidt-Strasse
4600 Dortmund 50 (Eichlinghofen)

BOOK REVIEWS: 1981

Ariman, T., Liu, S.C., and Nickell, R.E., eds., Lifeline Earthquake Engineering - Buired Pipelines, Seismic Risk and Instrumentation, ASME Special Publ. PVP-34, New York, NY, 1979; Reviewed by L.R.L. Wang, SVD, 13 (3), p 23 (Mar 1981)

Barr, D.F. and Miller, R.K., Basic Industrial Hearing Conservation, Fairmont Press, Atlanta, GA, 1979; Reviewed by R.J. Peppin, SVD, 13 (9), pp 37-38 (Sept 1981)

Bendat, J.S. and Piersol, A.G., Engineering Applications of Correlation and Spectral Analysis, John Wiley and Sons, New York, NY, 1980; Reviewed by H. Saunders, SVD, 13 (11), pp 25-26 (Nov 1981)

Bennett, S.E., Ross, A.L., and Zemanick, P.Z., eds., Failure Prevention and Reliability, ASME, New York, NY, 1977; Reviewed by H. Saunders, SVD, 13 (1), p 30 (Jan 1981)

Blekhman, I.I., ed., Nonlinear Vibration of Mechanical Systems, Volume 2 of Vibratsii v Tekhnike (Engineering Vibration, Chelomei, V.N., ed., Mashinostroenie, Moscow, 1979 (in Russian); Reviewed by M. Dublin, SVD, 13 (3), p 25 (Mar 1981)

Bolotin, V.V., ed., Vibration of Linear Systems, Volume 1 of Vibratsii v Tekhnike (Engineering Vibration), Chelomei, V.N., ed., Mashinostroenie, Moscow, 1978 (in Russian); Reviewed by M. Dublin, SVD, 13 (3), pp 24-25 (Mar 1981)

Bolotin, V.V., Sluchainye Kolebaniya Uprugikh Sistem (Random Vibration of Elastic Systems), Nauka, Glavnaya Redaktsiya Fiziko-matematicheskoi Literatury, Moscow, 1978 (in Russian); Reviewed by M. Dublin, SVD, 13 (7), p 15 (July 1981)

Buzdugan, G., Mihailescu, E., and Rades, M., Vibration Measurement, Rumanian Socialist Republic Academic Press, 1979 (in Rumanian); Reviewed by P. Ibanez, SVD, 13 (1), pp 31-32 (Jan 1981)

Carneiro, F.L.L.B., Ferrante, A.J., and Brebbia, C.A., eds., Offshore Structures Engineering, Gulf Publishing Co., Houston, TX, 1979; Reviewed by K.E. McKee, SVD, 13 (4), p 29 (Apr 1981)

Chen, S.S. and Bernstein, M.D., eds., Flow Induced Vibrations, ASME, New York, NY, 1979; Reviewed by D.W. Sallet, SVD, 13 (6), pp 19-21 (June 1981)

Clarkson, B.L., ed., Stochastic Problems in Dynamics, Fearon-Pitman Publ., Belmont, California; Reviewed by H. Saunders, SVD, 13 (4), pp 29-30 (Apr 1981)

Close, C.M. and Frederick, D.K., Modeling and Analysis of Dynamic Systems, Houghton Mifflin Co., Boston, MA, 1978; Reviewed by J.M. Prentis, SVD, 13 (9), pp 36-37 (Sept 1981)

Decker, K.-H., Maschinenelemente, Gestaltung und Berechnung, 7th Edition, Carl Hauser Vg., München, Fed. Rep. Germany, 1975 (in German); Reviewed by G. Schweitzer, SVD, 13 (2), pp 21-22 (Feb 1981)

Edelen, D.G.B., Lagrangian Mechanics of Nonconservative Nonholonomic Systems, Noordhoff International Publishing, Leyden, The Netherlands, 1977; Reviewed by H.K. Sachs, SVD, 13 (1), p 31 (Jan 1981)

Irons, B. and Ahmad, S., Techniques of Finite Elements, John Wiley and Sons, Somerset, NJ, 1980; Reviewed by A.J. Kalinowski, SVD, 13 (10), pp 37-38 (Oct 1981)

Kawata, K. and Jumpei, S., eds., High Velocity Deformation of Solids, Springer-Verlag, Berlin, 1978; Reviewed by S.E. Benzley, SVD, 13 (2), p 21 (Feb 1981)

Kuttruff, H., Room Acoustics, Applied Science Publishers, Ltd., London, UK, 2nd Edition, 1979; Reviewed by D.M. Yeager, SVD, 13 (11), pp 23-24 (Nov 1981)

Lalanne, M., Berthier, P., and Der Hagopian, J., Mécanique Des Vibrations Linéaires, Masson Publ., Paris, France, 1980 (in French); Reviewed by F.C. Nelson, SVD, 13 (8), pp 30-31 (Aug 1981)

Lyons, R.H., Statistical Energy Analysis of Dynamic Systems, MIT Press, Cambridge, MA; Reviewed by H. Saunders, SVD, 13 (12), pp 27-28 (Dec 1981)

Mader, C.L., Numerical Modeling of Detonations, University of California Press, Berkeley, CA, 1979; Reviewed by J.J. Dick, SVD, 13 (6), pp 18-19 (June 1981)

Magrab, E.B., Vibrations of Elastic Structural Members, Sijthoff & Noordhoff, Alphen aan den Rijn, The Netherlands, 1979; Reviewed by K.E. McKee, SVD, 13 (4), pp 30-31 (Apr 1981)

Main, I.G., Vibrations and Waves in Physics, Cambridge University Press, New Rochelle, NY, 1978; Reviewed by A.J. Kalinowski, SVD, 13 (11), pp 24-25 (Nov 1981)

Major, A., Dynamics in Civil Engineering: Analysis and Design, Akadémiai Könyvkiadó, Budapest, Hungary, Vol. I-IV, 1981; Reviewed by R. Szilard, SVD, 13 (12), p 29 (Dec 1981)

Nayfeh, A.H. and Mook, D.T., Nonlinear Oscillations, John Wiley and Sons, New York, NY, 1979; Reviewed by R.A. Ibrahim, SVD, 13 (5), pp 31-32 (May 1981)

Oden, J.T. and Reddy, J.N., Variational Methods in Theoretical Mechanics, Springer-Verlag, Vienna and New York, 1976; Reviewed by H. Saunders, SVD, 13 (10), p 39 (Oct 1981)

Otnes, R.K. and Enochson, L., Applied Time Series Analysis - Volume 1. Basic Techniques, John Wiley and Sons, New York, NY, 1978; Reviewed by H. Saunders, SVD, 13 (9), pp 38-40 (Sept 1981)

Paul, B., Kinematics and Dynamics of Planar Machinery, Prentice Hall, Inc., Englewood Cliffs, NJ, 1979; Reviewed by H. Saunders, SVD, 13 (8), pp 29-30 (Aug 1981)

Paz, M., Structural Dynamics Theory and Computation, Van Nostrand Reinhold Co., New York, NY, 1980; Reviewed by K.E. McKee, SVD, 13 (5), p 30 (May 1981)

Perrone, N. and Pilkey, W., eds., Structural Mechanics Software Series, Volume III, University Press of Virginia, Charlottesville, VA, 1980, Reviewed by M.M. Hurwitz, SVD, 13 (6), p 19 (June 1981)

Phillips, O.M., The Dynamics of the Upper Ocean, Cambridge University Press, New Rochelle, NY, 2nd Edition, 1977; Reviewed by J.R. Breton, SVD, 13 (10), p 37 (Oct 1981)

Pipes, R.B., ed., Nondestructive Evaluation and Flaw Criticality for Composite Materials, American Society for Testing and Materials (STP 696), Philadelphia, PA, 1979; Reviewed by S.E. Benzley, SVD, 13 (8), p 30 (Aug 1981)

Prentis, J.M., Dynamics of Mechanical Systems, Halsted Press, New York, NY, 2nd Edition, 1980; Reviewed by H.J. Sneck, SVD, 13 (12), pp 28-29 (Dec 1981)

Rades, M., Identification of Vibrating Systems, Rumanian Socialist Republic Academic Press, 1979 (in Rumanian); Reviewed by P. Ibáñez, SVD, 13 (2), pp 22-23 (Feb 1981)

Rosenberg, R.M., Analytical Dynamics of Discrete Systems, Plenum Press, New York, NY, 1977; Reviewed by R.A. Scott, SVD, 13 (3), pp 22-23 (Mar 1981)

Simiu, E. and Scanlan, R.H., Wind Effects on Structures, John Wiley and Sons, New York, NY, 1980; Reviewed by K.E. McKee, SVD, 13 (5), pp 30-31 (May 1981)

Taplin, D.M.R., Advances in Research on the Strength of Metals, Volume 2B - Fatigue, Pergamon Press, New York, NY, 1978; Reviewed by H. Saunders, SVD, 13 (7), pp 15-16 (July 1981)

Tominari, N., Seto, K., and Okada, J., Analysis and Design of Servo Control Systems, Corona Publishing Co., Ltd., Tokyo, Japan, 1979 (in Japanese); Reviewed by T. Iwatsubo, SVD, 13 (7), pp 16-17 (July 1981)

SHORT COURSES

JANUARY

PROBABILISTIC AND STATISTICAL METHODS IN MECHANICAL AND STRUCTURAL DESIGN

Dates: January 11-15, 1982
Place: Tucson, Arizona
Objective: The objective of this short course and workshop is to review the elements of probability and statistics and the recent theoretical and practical developments in the application of probability theory and statistics to engineering design. Special emphasis will be given to fatigue and fracture reliability.

Contact: Special Professional Education, Harvill Building No. 76, Room 237, College of Engineering, The University of Arizona, Tucson, AZ 85721 - (602) 626-3054.

MACHINERY VIBRATION ANALYSIS

Dates: January 26-29, 1982
Place: Tampa, Florida
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow speed paper rolls.

Contact: Dr. Ronald L. Eshleman, The Vibration Institute, 101 West 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

FEBRUARY

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: February 1-5, 1982
Place: Santa Barbara, California
Dates: March 1-5, 1982
Place: College Park, Maryland
Dates: April 12-16, 1982
Place: Dayton, Ohio
Dates: July 19-23, 1982
Place: England
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

VIBRATION TESTING AND SIGNAL ANALYSIS

Dates: February 16-18, 1982
Place: Southampton, England
Objective: Topics include: types of testing introduction to the various types of signal-linear system theory, etc. (i) testing with applied excitation - techniques - steady state, slow sweep, transient, random, (ii) response analysis (only) - system in motion due to natural excitation; instrumentation and signal conditioning - effects of attachments on system characteristics; instrumentation system characteristics; limitations, e.g. bandwidth, integration, analogue filtering, etc; signal processing; and specification testing.

Contact: Mrs. G. Hyde, ISVR Conference Secretary, The University, Southampton, S09 5NH - (0703) 559122, Ext. 2310.

BALANCING OF ROTATING MACHINERY

Dates: February 23-26, 1982
Place: Galveston, Texas

Objective: The seminar will emphasize the practical aspects of balancing in the shop and in the field. The instrumentation, techniques, and equipment pertinent to balancing will be elaborated with case histories. Demonstrations of techniques with appropriate instrumentation and equipment are scheduled. Specific topics include: basic balancing techniques (one- and two-plane), field balancing, balancing without phase measurement, balancing machines, use of programmable calculators, balancing sensitivity, flexible rotor balancing, and effect of residual shaft bow on unbalance.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MARCH

MEASUREMENT SYSTEMS ENGINEERING
Dates: March 1-5, 1982
Place: Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS
Dates: March 8-12, 1982
Place: Phoenix, Arizona
Objective: Program emphasis is on how to increase productivity, cost-effectiveness of data acquisition systems and groups in the field and in the laboratory. Emphasis is also on electrical measurements of mechanical and thermal quantities.

Contact: Peter K. Stein, 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

SHOCK AND VIBRATION CONTROL
Dates: March 16-18, 1982
Place: Southampton, England
Objective: Topics include: introduction - structural parameters and their role in vibration control; dynamic properties of structural materials - damping materials and their properties, application of damping treatments to structures, fibre reinforced plastics, fatigue; mobility methods - concepts, system coupling, application to the isolation problem, approximate methods; vibration transmission through structures - path identification - classical, cross correlation, etc., power flow - mechanisms, use of statistical energy methods, acoustic radiation, radiation efficiency; shock - impacts in machines - effects of structural parameters on acoustic radiation, isolation - machinery installations, the transient environment - packaging and packaging materials.

Contact: Mrs. G. Hyde, ISVR Conference Secretary, The University, Southampton, S09 5NH - (0703) 559122, Ext. 2310.

APRIL

DESIGN OF FIXED OFFSHORE PLATFORMS
Dates: April 5-16, 1982
Place: Austin, Texas
Objective: This course is dedicated to the professional development of those engineers, scientists, and technologists who are and will be designing fixed offshore platforms to function in the ocean environment from the present into the twenty-first century. The overall objective is to provide participants with an understanding of the design and construction of fixed platforms, specifically the theory and processes of such design and the use of current, applicable engineering methods.

Contact: Continuing Engineering Studies, College of Engineering, Ernest Cockrell Hall 2.102, The University of Texas at Austin, Austin, TX 78712 - (512) 471-3506.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

COMPILATION OF DAMPING DESIGN GUIDE

The Flight Dynamics Laboratory, one of the Air Force Wright Aeronautical Laboratories located at Wright-Patterson Air Force Base Ohio, awarded a three-year contract in September 1981 to Lockheed-California Company, Burbank, California and University of Dayton Research Institute, Dayton, Ohio, to develop an aerospace structures technology damping design guide. The objective of this effort is to collect and summarize available design methods and data on acoustic and vibration control using damping materials/methodology and compile this information into a damping design guide which may be readily applied for use in controlling structure and equipment vibration problems on board aircraft, spacecraft, and other aerospace systems. The design guide will be written for aerospace systems designers and provide to the designer the methods of damping design, limits of application, sources of derivation, and examples illustrating the use of each method.

The scientific/engineering community is invited to offer examples of successful application of damping methods/technology and detailed background information for these examples for inclusion in the damping design guide. Data on available damping material adhesives and compounds are also of interest and will be included in the guide, as will a list of vendors active in this field.

Anyone interested in participating or offering information is urged to contact: J. Soovere, Lockheed-California Company, Dept 63G, Plant A-1, Burbank, California 91520 - (213) 847-2225; M. Drake, University of Dayton Research Institute, Dayton, Ohio 45469 - (513) 229-2644; or V. Miller, Flight Dynamics Laboratory, AFWAL/FIBED, Wright-Patterson Air Force Base Ohio 45433 - (513) 255-5229/5753.

ERRATA

The following errors were noted in the article ***Linear Dynamic Thermoelasticity - A Survey,*** published in the September issue of the Digest.

"The **head** conduction equation," page 4, should read "The **heat** conduction equation."

"The **functions** $\underset{\sim}{\rho}, \underset{\sim}{\lambda}$ . . . ," page 4, should read "The **parameters** $\underset{\sim}{\rho}, \underset{\sim}{\lambda}$ . . . ."

"The **function** $\underset{\sim}{\theta}_o$ in equation (3) . . . ", page 5, should read "The **parameter** $\underset{\sim}{\theta}_o$ in equation (3) . . . ."

INFORMATION RESOURCES

THE METAL MATRIX COMPOSITES INFORMATION ANALYSIS CENTER

MISSION

The MMCIAC, established in October 1980, is one of the newest of the DoD information analysis centers (IACs) administered and funded by the Defense Logistics Agency (DLA) and the Defense Technical Information Center (DTIC). As with the other IACs, the MMCIAC receives its technical sponsorship and guidance from a DoD laboratory, in this case the U.S. Naval Surface Weapons Center at Silver Spring, Maryland. Kaman Temp (a division of Kaman Sciences ›rporation) located in Santa Barbara, California, operates and manages the MMCIAC.

The broad mission of the MMCIAC is to provide scientific and technical information analysis service to the DoD, other government agencies, government contractors, and the private sector in the area of metal matrix composite materials.

MMC TECHNOLOGY PROGRAM

Throughout the past decade the DoD has manifested a strong interest in developing Metal Matrix Composite (MMC) materials and has invested an estimated 70 million dollars in this technology over the past ten years. In the late 1970s a MMC "thrust" was implemented to further accelerate the developmental pace. The results of recent efforts directed by the Army, Navy, Air Force, and Defense Advanced Research Projects Agency (DARPA) has advanced the MMC community rapidly toward systems applications. Present efforts focus on making this new technology more cost effective.

The MMC technology program, over the past 12 years, however, has resulted in a growing, but fragmented data base. Current programs are producing a large amount of technical data and information that, within a short time, will equal and possibly surpass all the data previously generated. Therefore, a need exists to centrally accumulate, evaluate, analyze, and disseminate this technical data and information through a well developed and dedicated technology transfer program. The DoD Metal Matrix Composites Information Analysis Center was established as the basic element of such a program.

TECHNICAL SCOPE

The subject matter coverage of the MMCIAC is the technology related to metal matrix composite materials. The materials are understood to be those composites that perform acceptably under severe conditions, both environmental and operational. The materials are those characterized as having high specific properties, proven environmental fatigue capability, reduced requirement for critical metals, improved creep and wear resistance, high design flexibility, high damage tolerance, and unique combinations of properties including mechanical, electrical, and thermal. The scope of this coverage embraces:

- Continuous fibers, wires, discontinuous whiskers with L/D 10, directionally solidified eutecitics
- Fibers -- boron, graphite, silicon carbide, borsic, nitride, alumina, boron carbide, titanium diboride
- Wires -- stainless steel, tungsten, molybdenum, beryllium, titanium, niobium alloys and compounds
- Whiskers -- alumina, silicon carbide, silicon nitride
- MMC Systems -- alumina/magnesium, beryllium/titanium, boron/stainless steel/aluminum, boron/titanium/aluminum, borsic/aluminum, borsic/titanium, copper/graphite, graphite/lead, graphite/aluminum, tungsten/nickel.

Technical areas of interest for the MMCIAC include: manufacturing, fabrication process development,

defense systems applications, performance computations, cost, test and evaluation techniques and methods, properties data, operational serviceability and repair, environmental protection, sources, suppliers, and other MMC-related areas.

MMC PROPERTIES DATA BASE

A special function of the Center is to establish and maintain an MMC properties data base from which to develop information useful to designers concerned with MMC applications. Documents acquired by the Center may contain or reference MMC test data that substantiate derived conclusions and/or analytical results. In these instances, supporting test data are examined and screened for potential MMCIAC data base incorporation. Properties and test data selected for incorporation are evaluated, formatted and placed into an MMC data base organized for selective retrieval and analysis. The data summaries or data books produced from the MMC data base will be disseminated periodically to the Center's users.

INFORMATION OPERATIONS

The MMCIAC provides the facilities and capabilities to: (1) identify, collect, process, store, and disseminate authoritative MMC information; (2) prepare or sponsor the preparation of the necessary products and services to communicate this information to researchers, practicing specialists, manufacturers, and other users with interests and concerns in metal matrix composites; and (3) coordinate and augment existing information activities to improve the transmittal of this information to interested organizations and individuals in the government, military, and private sector.

Center activities include the collection, review, evaluation, analysis, dissemination of the literature related to MMC materials, and assisting visitors in using data files. Emphasis is placed on screening, filtering, and selective reduction to maintain a data base that truly reflects the current state-of-knowledge. MMCIAC personnel continuously review, analyze, refine, and pool worldwide published and unpublished scientific and technical information acquired from the DoD and NTIS and recognized professionals in Government and contractor organizations. They also monitor publications of other IACs and data centers and actively participate in MMC technical conferences and symposia such as the MMC Technology Conference.

The Center's information sources include: Technical reports from DoD, other Government agencies, industry, and academic institutions, etc; open literature including foreign sources; unpublished papers; meetings; technical journals; conferences; workshops; and consultations with key scientists in the MMC community.

PRODUCTS AND SERVICES

The MMCIAC provides a central, authoritative, and easily accessible body of information consistent with MMC materials development and applications. Specifically, it is designed to provide:

- Continuous and comprehensive information acquisition and compilation
- On call, specialized user services for answering technical and bibliographic inquiries from qualified individuals and organizations
- State-of-the-art studies of MMC technology with usefulness extending from the bench level to all levels of RDT&E management
- Scientific and engineering reference works such as handbooks, design manuals and periodic MMC materials properties data summaries
- Critical reviews and assessments of MMC technology and related subjects of significant interest to the Defense RDT&E community
- Current awareness and other user-oriented publications in a quarterly newsletter, notices and proceedings of MMC and related conferences, and announcements with bibliographical accounts of newly acquired information. The quarterly newsletter is available without charge to any interested individual or company engaged in materials research, development, testing, fabrication, and/or applications.

ORGANIZATION AND STAFF

Technical Monitor

U.S. Naval Surface Weapons Center
ATTN: Code R32/Dr. Steven G. Fishman
White Oak Laboratory

Silver Spring, Maryland 20910
(202) 394-2724

Operator

Kaman Tempo (Formerly General Electric-Tempo)
816 State Street
P.O. Drawer QQ
Santa Barbara, California 93102
(805) 963-6497

Manager

Louis A. Gonzalez
Manager - Center Operations
(805) 963-6497

Service Points of Contact

Jacques E. Schoutens
Manager - Data Analysis
(805) 963-6462

William E. Rogers
Manager - Information Services
(805) 963-6482

ABSTRACT CATEGORIES

MECHANICAL SYSTEMS

Rotating Machines
Reciprocating Machines
Power Transmission Systems
Metal Working and Forming
Isolation and Absorption
Electromechanical Systems
Optical Systems
Materials Handling Equipment

STRUCTURAL SYSTEMS

Bridges
Buildings
Towers
Foundations
Underground Structures
Harbors and Dams
Roads and Tracks
Construction Equipment
Pressure Vessels
Power Plants
Off-shore Structures

VEHICLE SYSTEMS

Ground Vehicles
Ships
Aircraft
Missiles and Spacecraft

BIOLOGICAL SYSTEMS

Human
Animal

MECHANICAL COMPONENTS

Absorbers and Isolators
Springs
Tires and Wheels
Blades
Bearings
Belts
Gears
Clutches
Couplings
Fasteners
Linkages
Valves
Seals
Cams

STRUCTURAL COMPONENTS

Strings and Ropes
Cables
Bars and Rods
Beams
Cylinders
Columns
Frames and Arches
Membranes, Films, and Webs
Panels
Plates
Shells
Rings
Pipes and Tubes
Ducts
Building Components

ELECTRIC COMPONENTS

Controls (Switches, Circuit Breakers)
Motors
Generators
Transformers
Relays
Electronic Components

DYNAMIC ENVIRONMENT

Acoustic Excitation
Shock Excitation
Vibration Excitation
Thermal Excitation

MECHANICAL PROPERTIES

Damping
Fatigue
Elasticity and Plasticity

EXPERIMENTATION

Measurement and Analysis
Dynamic Tests
Scaling and Modeling
Diagnostics
Balancing
Monitoring

ANALYSIS AND DESIGN

Analogs and Analog Computation
Analytical Methods
Modeling Techniques
Nonlinear Analysis
Numerical Methods
Statistical Methods
Parameter Identification
Mobility/Impedance Methods
Optimization Techniques
Design Techniques
Computer Programs

GENERAL TOPICS

Conference Proceedings
Tutorials and Reviews
Criteria, Standards, and Specifications
Bibliographies
Useful Applications

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 2585, 2593, 2655, 2660, 2661, 2663, 2665, 2666, 2667, 2668, 2669, 2676, 2688)

81-2505

Recognition of the Causes of Rotor Vibration in Turbomachinery

D.M. Smith

Turbine Generator Div., Associated Electrical Industries, Ltd., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 1-4, 11 refs

Key Words: Rotors, Turbomachinery, Oil film bearings, Journal bearings, Vibration source identification

This paper discusses actions which influence rotor vibration and means of recognizing vibration set up by these actions. Attention is given primarily to rotors carried in oil-film journal bearings, as widely used in land and marine turbine plants. Stator vibration which contributes to rotor vibration is taken into account.

81-2506

Double-Frequency Accelerations in Turbogenerator Rotors Resulting from Anisotropy in the Bearings

W. Kellenberger

Brown Boveri, Birr, Switzerland, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 415-420, 5 figs, 3 tables

Key Words: Rotors, Turbogenerators, Acceleration effects, Bearings, Anisotropy

The motion of a turbogenerator rotor in any plane normal to the rotation axis is known to be elliptical. This results in alternating accelerations of all points of the shaft at double-rotation frequency. This paper is concerned with the calculation of these accelerations and the resulting alternating forces which act (at constant speed) on every rotor component (in addition to the steady centrifugal forces) and must be conveyed, over the component's attachment, to the main body of the rotor. Examples of attached components are: slot-wedges, balancing masses, ventilator fan blades and end-rings.

81-2507

Further Investigations into Load Dependent Low Frequency Vibration of the High Pressure Rotor on Large Turbo-Generators

S.H. Greathead and M.D. Slocombe

N.E. Region Scientific Services Dept., MIMechE, Otley Rd., Harrogate, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 401-413, 15 figs, 2 tables, 6 refs

Key Words: Rotors, Turbogenerators, Nonsynchronous vibration, Low frequencies

This paper presents results from a gland rig which has been built to measure unbalanced steam forces arising in multi-cell shaft labyrinth glands with different geometries and flow conditions. Further operational evidence from observations and measurements on this type of machine obtained during investigations into this load dependent vibration instability is also presented. The gland rig results indicate that large unbalanced steam forces can be generated from steam flow in shaft glands. The operational evidence supports this and also indicates that such forces make an important contribution to the load dependent h.p. rotor instability problems experienced.

81-2508

On the Influence of Casing Stiffness in Turbomachinery Vibration Analysis

S.S. Stecco and M. Pinzauti

Dept. of Energetics, Univ. of Florence, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 139-144, 8 figs, 3 refs

Key Words: Turbomachinery, Critical speeds, Interaction: rotor-casing

Critical frequencies of turbomachines are often highly affected by the interaction effects between casing and rotor. A method, original under various aspects, is presented in order to predict from theoretical values (or, in some cases, from experimental data) the vibrational behavior of the machine. A practical application is also given showing the numerical results.

81-2509

Modal Dynamic Simulation of Flexible Shafts in Hydrodynamic Bearings

H.F. Black and R.D. Brown
Heriot-Watt Univ., Edinburgh, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 109-113, 6 figs, 13 refs

Key Words: Rotors, Flexible shafts, Modal analysis, Nonlinear theories

The major sources of non-linearity in flexible rotors are the forces originating from hydrodynamic bearings. When large excitation forces occur, journal motion may be so great that nonlinearity must be considered. The calculation time for nonlinear simulation depends on the number of modes used and the lubricant film force model. An existing Rayleigh-Ritz linear program was adapted for numerical integration. Bearing oil films forces were obtained as time dependent functions using an approximate method. The results presented demonstrate that nonlinear effects can be significant for peak response levels.

81-2510

The Transient Response of Turbo-Alternator Rotor Systems under Short-Circuiting Conditions

J.S. Rao, D.K. Rao, and K.V. Bhaskara Sarma
Indian Inst. of Technology, New Delhi, India, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrg., pp 271-275, 4 figs, 1 table, 7 refs

Key Words: Rotors, Torsional vibration, Natural shapes, Transfer matrix method, Computer programs

Sudden short-circuiting conditions at the alternator end generate predominant transient torsional oscillations in a turbo-alternator rotor inducing severe dynamic stresses. To evaluate these stresses, a continuous transfer matrix model was developed to determine torsional frequencies and modes. A discrete dynamic system of specified number of rotors is extracted from continuous system and its modes are evaluated by Jacobian method. Transient response is evaluated by modal expansion method. A computer program was developed and the results for a 6MW turbo-alternator system are presented.

81-2511

An Approximate Formula for the Fundamental Frequency of a Uniform Rotating Beam Clamped off the Axis of Rotation

D.H. Hodges
Aeromechanics Lab., U.S. Army Research and Technology Labs. (AVRADCOM), Ames Res. Ctr., Moffett Field, CA, J. Sound Vib., 77 (1), pp 11-18 (July 8, 1981) 5 tables, 8 refs

Key Words: Rotors, Blades, Beams, Rotating structures, Fundamental frequency

A semi-empirical method involving asymptotic expansions is used to obtain an approximate formula for the fundamental frequency of a uniform rotating beam clamped off the axis of rotation. Results from the formula are shown to be of the order of 0·1% different from the exact results for a wide range of rotor speeds and hub radii up to the order of blade length. Thus, the designer is provided with a rapid, very accurate estimate of the frequency, without having to interpolate results from a chart or run a digital computer program.

81-2512

Finite Element Analysis of Rotating Disks

G.L. Nigh and M.D. Olson
Dept. of Civil Engrg., Univ. of British Columbia, Vancouver, British Columbia, Canada, J. Sound Vib., 77 (1), pp 61-78 (July 8, 1981) 8 figs, 1 table, 16 refs

Key Words: Disks (shapes), Rotating structures, Finite element technique, Critical speeds, Viscous damping

A finite element formulation is presented for the analysis of rotating disks in either a body-fixed or a space-fixed co-ordinate system. The in-plane stress distribution resulting from the in-plane body force due to rotation is determined first by a plane stress finite element analysis. This stress distribution is then used in calculating the out-of-plane geometric stiffness which in turn is added to the linear bending stiffness. In the space-fixed co-ordinate system, inertia and a viscous type damping also contribute to the out-of-plane stiffness, even in the steady state case. The formulation presented here places no restrictions on the disk geometry if the problem is solved in a body-fixed co-ordinate system, although only disks of axisymmetric geometry may be considered in the space-fixed co-ordinate system. A direct method of determining the critical speeds through an eigenvalue analysis in space-fixed co-ordinates is presented. The undamped steady state response to a space-fixed transverse point load is then examined. The effects of a viscous type damping are also presented.

81-2513

Reduction of Twice per Revolution Vibration Levels Due to Weight Effect in Large Turbogenerators

N. Bachschmid and G. Diana

Milan Polytechnic, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 203-208, 11 figs, 2 tables, 10 refs

Key Words: Rotors, Turbogenerators, Vibration control, Stiffness coefficients, Asymmetry

A method is presented for determining the rotating stiffness unequality from the statical deflection as well as from the twice per revolution vibration measurements. In this way it is possible to verify if, and how strong, dynamical effects due to rotating speed may change the statical stiffness unequality distribution. It is further possible to detect where corrections must be applied in order to reduce the twice per revolution vibration levels. This method was applied to a 600 MW generator and proved to be reliable and a successful tool "twice per revolution balancing."

81-2514

Relative Energy Concepts in Rotating System Dynamics

G.T.S. Done

The City Univ., London, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 283-287, 5 figs, 4 refs

Key Words: Rotors, Work and energy balance

The concept of relative work and energy; i.e., work and energy expressed relative to nonfixed axes, is not a commonly used one, but it is nevertheless just as valid as that of relative displacement, velocity and acceleration. The basic mechanics are presented in the paper, and it is shown how problems that have arisen in classifying certain types of rotating systems as conservative or nonconservative are resolved. Both absolute and relative energy balances are formulated for two models that exhibit mechanical instability; namely, an unsymmetric cross-section rotating shaft and the lag-plane ("ground resonance") model of a helicopter rotor.

81-2515

Instabilities of Parametric Rotor Support Systems

J. Krodkiewski, K. Marynowski, and Z. Parszewski

Politechnika Lódzka, Lódz, Poland, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 289-296, 15 figs, 5 refs

Key Words: Rotors, Supports, Parametric response, Stiffener effects

Analysis of instability regions and forced vibrations of parametric discrete/machine/subsystems, interacting with real/supporting/structures is given and applied to model machines with rotors of unequal principal stiffnesses. Laboratory test results are cited and compared with computed ones, regarding instability regions and types of instability, forced vibrations amplitudes and journal center loci. First four harmonics content was computed and plotted for full experimental speed range.

81-2516

A Physical Explanation of Parametric Instabilities in Unsymmetric Rotors

D.A. Peters and I. Zvolanek

Washington Univ., St. Louis, MO, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 77-82, 8 figs, 16 refs

Key Words: Rotors, Whirling, Flutter, Parametric excitation

Past work on instabilities in unsymmetric rotors has shown that instabilities can conceivably occur whenever the sum or difference of two natural frequencies equals an integer multiple of the rotor speed. It is also known that some of these potential instabilities are realized neither analytically nor experimentally. In this paper, rules are developed that predict which potential instabilities will occur in the presence of zero damping.

81-2517

Instability Threshold of an Unbalanced, Rigid Rotor in Short Journal Bearings

J.W. Lund and H.B. Nielsen

Dept. of Machine Elements, The Technical Univ. of Denmark, Denmark, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 91-95, 3 figs, 4 refs

Key Words: Rotors, Rigid rotors, Unbalanced mass response, Parametric excitation

The unbalance response of a rigid rotor in short journal bearings is considered. The whirl orbits are assumed to be elliptical at synchronous frequency and are determined from the method of averaging. The stability of the orbital motion is investigated on the basis of the variational equations which include the effect of parametric excitation. The calculated zones of instability are obtained as functions of the Sommerfeld number and a rotor mass parameter for several values of the mass unbalance. The results are shown in a diagram.

81-2518

Acceleration of Unbalanced Rotor through the Resonance of Supporting Structure

F. Victor and F. Ellyin

Dept. of Civil Engrg., Univ. of Sherbrooke, Sherbrooke, Quebec, Canada, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 419-424 (June 1981) 11 figs, 10 refs

Key Words: Rotors, Unbalanced mass response, Resonance pass through, Transverse shear deformation effects, Rotatory inertia effects, Internal damping, Viscous damping

The dynamic response of a simple beam excited at its midspan by the action of a turbomachine secured to it, is investigated in detail. The forcing function includes transients at startup or shutdown. Effects of the shear deformation, rotatory inertia, and the internal viscous damping, which may depend on the frequency, are considered individually as well as in combined forms. The results indicate that the maximum amplitude of vibration is highly dependent on the acceleration rate through the critical frequency. There is also an apparent shift in its position as compared to the classical resonance frequency. Influences of shear deformation and rotatory inertia are significant when the supporting structure (or foundation) is relatively massive.

81-2519

Fatigue and Fracture Analysis of Two Turbine Shafts

B.N. Leis, K. Dufrane, R. Rungta, R.D. Buchheit, M. Tuttle, P. Skulte, and S. Collard

Battelle Columbus Lab., Columbus, OH, ASME Paper No. 81-PVP-27

Key Words: Shafts, Fatigue life, Crack propagation

A coupled fractographic and mechanics based analysis of radical cracking problems in two low pressure steam turbine shafts is presented. Cracks occurred at circumferential notches cut in the shaft near shrunk-on discs. Fractography showed fatigue cracks initiated at these notches from pits developed under the action of cyclic bending in a wet stream/condensate environment. Favorable comparison between predicted growth rates and observed growth rates suggest that for this study, fracture mechanics represents a viable tool for turbine shaft design and failure analysis, at least during the crack growth stage. Results also indicate that once the crack is initiated, failure will occur in a matter of days so that corrosion fatigue crack nucleation and the growth of very small cracks dominates the failure process.

81-2520

A Method of Calculating the Vibrational Behaviour of Coupled Rotating Shafts Containing a Transverse Crack

I.W. Mayes and W.G.R. Davies

Central Electricity Generating Board, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 17-27, 9 figs, 9 refs

Key Words: Shafts, Cracked media

A method of calculating the vibrational response of a coupled rotor system to a transverse crack using standard finite-element computer programs is briefly described. The method employs the technique of successive approximations and utilizes the fact that the fractional change in stiffness of a rotor is small even for large cracks and that for speeds away from critical speeds of the shaft, the crack opening and closing is dominated by self-weight bending. The method has been validated by comparing calculations with the experimental results from a four-bearing, two-shaft spin rig, one of whose shafts has a propagating transverse crack. The application of the method to two suspect turbo-generators is described.

81-2521

On the Occurrence of Unstable Vibrations of a Shaft Having Either Asymmetrical Stiffness or Asymmetrical Rotor, Supported by Asymmetrically Flexible Pedestals

H. Ota and K. Mizutani

Dept. of Mech. Engrg., Faculty of Engrg., Nagoya Univ., Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge,

UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 181-186, 6 figs, 1 table, 8 refs

Key Words: Shafts, Rotors, Variable material properties, Vibration response

In a rotating shaft with unequal stiffness or with an asymmetrical rotor, two kinds of unstable vibrations occur. In this paper, the mechanisms which cause the occurrence of unstable vibrations are clearly explained. Conditions under which unstable vibrations occur are derived and ascertained by use of an analog computer.

81-2522

Vibration of a Rotating Shaft Passing through Two Critical Speeds

S. Yanabe and A. Tamura

Tokyo Inst. of Technology, Tokyo, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 19-35, 6 figs, 2 tables, 11 refs

Key Words: Shafts, Critical speeds, Damping effects

The vibration of a rotating shaft which passes through two critical speeds successively under the condition of the uniform acceleration rate is analyzed theoretically taking account of the damping force. The exact solution and its approximate expressions of the nonstationary vibration are derived and their calculated results with respect to various values of the critical speed ratio n and the acceleration parameter Ω_1 are shown. Both results have a good agreement in a wide speed range including the maximum amplitude.

81-2523

A Technique for Modelling Rotors from Measured Vibration Characteristics

G.B. Thomas and P. Littlewood

Central Electricity Generating Board, Harrogate, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 445-451, 6 figs, 1 table, 9 refs

Key Words: Rotors, Mathematical models, Natural frequencies, Mode shapes, Measurement techniques, Stiffness coefficients

The accuracy of rotordynamic calculations is governed by the quality of the available computer model, which for turbo-alternator plant includes three main elements: rotor, bearings and foundations. Existing rotor models are constructed from manufacturers' sectional data idealized empirically to include the stiffening effect of abrupt changes of diameter. A technique for measuring the natural frequencies and modal shapes of individual rotors is described. The measurements were originally intended for comparison with calculations but a method was later developed for calculating an effective stiffness profile from the measured modal shape which was then used to construct a new improved rotor model. Results of rotordynamic calculations from the existing and improved computer models are presented and compared with measured data. The technique has also been used successfully for locating the axial position of rotor cracks.

81-2524

A Contribution for the Calculations of Intermittent Vibrations of Electrically Driven Rotors

U. Hollburg

Technische Universität, Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 339-346, 7 figs, 8 refs

Key Words: Motors, Rotors, Shafts, Amplitude analysis

During the planning of driving mechanisms, consisting of an electromotor, a coupling for the abutting shafts and a processing machine, it is necessary to assess the maximum ratings of the shafts produced by bending and torsional moments. Knowledge is required of the maximum amplitude during intermittent working conditions. Intermittent phenomena of motion of overcritical rotors appear mainly during the running-up since the bending (torsional critical speed) must be passed through until the nominal values are reached. In order to judge the vibrational behavior at the very beginning, the simultaneous consideration of the mechanical system and the electromagnetic process is indispensable. For the description of the various models, a symbolical rotor system is chosen from the many possible driving mechanisms. The continuous bending and torsional elastic shafts with circular cross sections are mounted orthotropically. These shafts are connected by a coupling which is assumed to be elastic. Mathematically, the problem is described by partial differential equations but the complete analytical solution is not obtainable. Thus the problem will be approximately solved by, first of all, determining the Eigenmode of the appointed conservative structure for a discretized finite element model. By means of a connected modal transformation a set of ordinary nonlinear differential equations is obtained for which a numerical solution is possible.

81-2525

Torsional Vibrations During the Starting Process in Driving Systems with Three Phase Motors

H. Peeken, C. Troeder, and G. Diekhans

Inst. of Machine Elements and Machine Design, Technical Univ. Aachen, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 427-435, 16 figs, 2 tables, 3 refs

Key Words: Motors, Torsional vibration, Shafts, Drive shafts, Rotating machinery

Induction and synchronous machines produce an oscillation torque on starting which causes strong torsional excitation in connected machinery. A method to measure the air gap torques of the machines in driving systems is presented. With the help of a mathematical model of the machines, it is possible to calculate by digital simulation the torsional response in shaft systems considering that electrical and mechanical system are coupled. Parameter variations in the mechanical system show the dominant effects influencing the air gap torque produced during starting.

81-2526

Investigation of a D.C. Motor Vibration Problem

D. France and H. Grainger

Dynamics Section, Weir Pumps Ltd., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 83-90, 9 figs, 2 refs

Key Words: Motors, Vibration source identification, Resonant frequencies, Mountings, Elastomers

A severe vibration problem was experienced with a D.C. motor used to provide the drive for a paper making machine. The vibration frequency was found to be at the rotor slot number multiplied by rotational speed and distinct resonant regions were evident within the motor operating speed range. The paper describes the various steps taken to identify the excitation source and determine the characteristics of the resonant modes of vibration. Various solutions to the problem were considered and are described. The final solution was achieved by use of an elastomeric mounting arrangement for the motor bearings.

81-2527

Computation of Vibrations of the Coupled System Machine-Foundation

E. Krämer

Technische Hochschule Darmstadt, German Federal Republic, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 333-338, 10 figs, 2 tables

Key Words: Interaction: rotor-foundation, Journal bearings, Rotors, Foundations, Stiffener effects, Vibration response

A procedure is given for computing the unbalance vibrations of rotor-foundation systems. First the foundation is calculated separately. Its influence on the rotor system is represented by its dynamic stiffness at the connecting points to the rotor. With this the expense for computation is reduced to an acceptable level. According to some studies, in many cases it may be possible to assume the foundation as a rigid supporting base.

81-2528

Vibration Analysis of Large Rotor-Bearing-Foundation-Systems Using a Model Condensation for the Reduction of Unknowns

M. Jäcker

Technical Univ., Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 195-202, 10 figs, 4 refs

Key Words: Rotors, Interaction: rotor-foundation

For the dynamic analysis of many rotating structures it is necessary to take into account the dynamic behavior of their foundations. The high analysis costs due to the known complexity of the system can considerably be reduced by a reduction of the unknowns which is based on the speed-independent modal properties of the system components (modal condensation, component mode method). The technique is applied to different linear dynamic problems (stationary and transient response, critical speeds, stability) in a consistent manner. Numerical examples are given for the stationary response problem.

81-2529

Defining the Machine/Foundation Interface

P.E. Simmons

Petrochemical Div., ICI Ltd., Wilton, Middlesbrough, Cleveland, OH, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge,

UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 5-8, 5 figs, 1 ref

Key Words: Interaction: rotor-foundation, Rotors, Foundations

As turbo-machines get larger their dynamic behavior is increasingly affected by the flexibility of their bearings, support structures and foundations. Also larger machines tend to require taller and generally more flexible foundations which are inadequately represented in the machine designer's mathematical model. There is a need for a system which adequately defines the interface and quantifies those characteristics of the foundations which are important to the machine designer. The purpose of this paper is to suggest a standard system of defining the interface which would enable the civil engineer to present the dynamic characteristics of the foundation in a form which the machine designer can use in an improved mathematical model to determine the dynamic behavior of the machine.

81-2530

Stresses of Turbo-Generator Shafts and Foundations Caused by Electrical System Faults

Th. Jainski

Technical Univ., Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 9-16, 10 figs, 11 refs

Key Words: Interaction: rotor-foundation, Rotors, Foundations, Electric systems

Turbo-generator shafts and foundations are transiently excited by electrical system faults like terminal short circuits, faulty synchronizing, clearing of network short circuits near to the power plant. Abnormal mechanical stressing in rotor and foundation is caused by pulsating electromagnetic forces. They have to be taken into account by dynamic stress investigations of both structures. An accurate determination of local stress values demands complex mathematical models (FEM) and time-consuming numerical investigations (time-history-method) in order to solve the equations of motion. A large FEM-modeled turbo-shaft and foundation were treated by the exact but time-consuming time-history-method and the response-spectra-method as an economical method of approximation considering the dynamic character of the problem. In addition, the dynamic stress of foundations was evaluated by a quasi static analysis according to the old German Standard DIN 4024.

81-2531

Seismic Response of a Flexible Rotor

T. Shimogo and M. Nakano

Keio Univ., Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 321-326, 20 figs, 4 tables, 4 refs

Key Words: Rotors, Flexible rotors, Seismic response

The results of seismic response analysis of a flexible rotor supported by two bearings, in which the dynamic properties are represented by linear springs and dampers, are presented. For the simplification of a theoretical treatment the rotor is represented as either a lumped or a uniformly distributed parameter system, and gyroscopic moments are included. The seismic excitations acting on two bearings are assumed to be a stationary Gaussian random process with a dominant frequency such as the El Centro earthquake waveform. In particular, the influences of a flexibility of rotor upon the seismic responses; i.e., the relative displacement of the rotor, the dynamic loading of the bearings, and so on, are studied. Numerical examples of a generator-rotor of 350MW steam power plant indicate the fact that the maximum r.m.s. responses are considerably bigger than those obtained on the assumption of a rigid rotor, due to a decreasing fundamental resonance frequency. Influence of rotor speed on the seismic response is also examined.

81-2532

Dynamics of High Speed Rotative Assemblies

D.A. Thurgood

British Aerospace Dynamics Group, Hatfield Div., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 389-393, 7 figs, 1 table, 1 ref

Key Words: Compressors, Rotary compressors, Turbomachinery, Balancing techniques, Damping

Presentation is made of the development experience of a series of high speed turbocompressor units for aircraft air-conditioning systems with particular reference to aspects of balancing, shaft response and damping, and excitations from angular contact ball bearings.

81-2533

Analysis and Design of Centrifugal Pumps Considering Rotor Dynamics

M. Takagi, O. Matsushita, T. Ino, K. Kikuchi, and K. Komatsu

Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 43-51, 16 figs, 1 table, 11 refs

Key Words: Pumps, Centrifugal pumps, Friction excitation

In this paper rotational bending stress analysis of centrifugal pump rotors, imbalance response analysis, stability analysis of self-excited vibration and unsteady response analysis due to rubbing are developed. Systematic tests corresponding to these analyses are carried out using actual multi-stage centrifugal pumps. The calculated values agreed well with the experimental values with regard to the stability-threshold speed, and the steady state rotational bending stresses. Qualitative agreement was obtained with regard to the behavior of transient stress due to rubbing. On the basis of these results, methods of estimating the vibration responses and bending stresses in the high speed large-scale multi-stage centrifugal pumps, and pump design methods considering these factors are established.

RECIPROCATING MACHINES

81-2534

Energy Conservation and Noise Control in Pneumatic Devices and Systems, Part II - Percussive Tools, Blow-offs and Air Ejectors

M.D. Oviatt

Richard K. Miller & Associates, Inc., Alpharetta, GA, Plant Engineering, 35 (16), pp 116-118 (Aug 6, 1981) 2 figs

Key Words: Hand tools, Noise reduction

Noise reduction techniques of hand held reciprocating tools, such as chipping hammers, needle scalers, sand rammers, rock drills, pavement-breakers, blow-off nozzles, and air ejectors, are presented.

METAL WORKING AND FORMING

(See No. 2664)

STRUCTURAL SYSTEMS

BUILDINGS

(Also see Nos. 2561 and 2691)

81-2535

The Tenth Sir Richard Fairey Memorial Lecture: Sound Transmission in Buildings

M. Heckl

Institut f. Technische Akustik, Technische Universität Berlin, D-1000 Berlin 10, Germany, J. Sound Vib., 77 (2), pp 165-189 (July 22, 1981) 22 figs, 2 tables, 27 refs

Key Words: Buildings, Sound transmission

Sound transmission through walls, ceilings, windows, doors, etc., depends on (1) mass per unit area, (2) bending stiffness, (3) damping, (4) variation in bending stiffness (because of struts or other anisotropies), (5) stiffness and damping of interlayers and sound bridges (in cases of double walls), (6) size and shape of partitions, (7) mounting conditions, (8) influence of flanking walls, (9) unwanted effects such as slits, etc. The first three parameters and to a certain degree also the fourth and fifth can be dealt with theoretically by investigating walls of infinite size. In this way many of the results obtained in buildings can be explained at least qualitatively. The influences of size, shape, mounting conditions and the influence of flanking transmission can be understood best by applying energy balance equations, and in this way the average behavior of reasonably large constructions can be explained.

81-2536

Approximate Method for Lateral Load Analysis of High-Rise Buildings

F.K.E.C. Mortelmans, G.P.J.M. de Roeck, and D.A. Van Gemert

Struct. Engrg. Dept., Katholieke Universiteit Leuven, Belgium, ASCE J. Struc. Div., 107 (ST8), pp 1589-1610 (Aug 1981) 16 figs, 1 table, 7 refs

Key Words: Framed structures, Multistory buildings, Buildings, Wind-induced excitation, Columns

An approximate method for the design of long, high-rise buildings under horizontal wind loading is described. The method is based on the reduction of the framed structure to one built-in column with equivalent bending and torsional stiffnesses. Discrete actions of the horizontal members on the columns are distributed over the story heights. The floors are treated as rigid in the horizontal plane. The calculation is reduced to the solution of a system of four linear equations; the determination of internal actions only requires some very simple operations. The accuracy of the method is demonstrated by comparison to the displacement method.

81-2537

Torsional Coupling and Earthquake Response of Simple Elastic and Inelastic Systems

C.L. Kan and A.K. Chopra

Dept. of Civil Engrg., Univ. of California, Berkeley, CA, ASCE J. Struc. Div., 107 (ST8), pp 1569-1588 (Aug 1981) 16 figs, 1 table, 8 refs

Key Words: Buildings, Earthquake response, Torsional response, Lateral response

The effects are analyzed of torsional coupling on the earthquake response of simple one-story structures in elastic and inelastic ranges of behavior. The structures considered are symmetrical about one principal axis of resistance, resulting in coupling only between lateral displacement along the perpendicular axis and the torsional displacement. Torsional coupling arising only from eccentricity between centers of mass and elastic resistance is considered. Systems with several resisting elements are idealized by a single element model. Response of such a model to a selected earthquake ground motion are presented for a range of the basic structural parameters. The response quantities presented include maximum lateral and torsional deformations of the system as well as maximum deformations of individual columns. The response in the inelastic range of behavior is effected by torsional coupling to generally a lesser degree than elastic response.

TOWERS

81-2538

Measurements of Wind and Deformation on a High Radio Tower. Part 3. Measurement (Wind- und Verformungsmessungen an einem Funkturm. Teil 3. Messungen)

W. Neuerburg

Maschinenlaboratorium 2 der Fachhochschule für Technik Esslingen, Kanalstr, Esslingen, Germany, Techn. Messen-ATM, 7/8, pp 275-280 (July/Aug 1981) 13 figs, 1 ref

(In German)

Key Words: Towers, Wind induced excitation, Experimental test data

The wind loadings on a high tower structure and the coherent effects of static and dynamic responses were studied by means of versatile measurement equipment. Wind pressures against the tower wall, the deformation and oscillation of the structure and the free-streaming wind were measured with reference to the time.

FOUNDATIONS

(Also see Nos. 2527, 2529, 2530)

81-2539

Plastic Models in Turbomachinery Foundation Studies

R.L. Bannister and J.K. Aneja

Westinghouse Electric Corp., Lester, PA, ASCE J. Engr. Mech. Div., 107 (EM4), pp 649-667 (Aug 1981) 13 figs, 1 table, 22 refs

Key Words: Turbomachinery, Machine foundations, Resonant frequencies, Mode shapes, Experimental test data, Model testing

Over a period of years, the static and dynamic behavior of turbomachinery foundations have been studied with scaled plastic models. Experimental data from several investigators show the type of information that can be obtained for resonant frequencies, mode shapes and response levels in the laboratory. Model test data are compared with measurements made on full-size structures and also calculated from analytical models. Accuracy is dependent on the degree to which similitude requirements are met. Experimental results are also presented to show how structural models have been used to determine the effect of foundation termination, rotor unbalance and bearing support stiffness.

UNDERGROUND STRUCTURES

81-2540

Numerical Simulations of Earthquake Effects on Tunnels for Generic Nuclear Waste Repositories

K.K. Wahi, B.C. Trent, D.E. Maxwell, R.M. Pyke, and C. Young

Science Applications, Inc., Fort Collins, CO, 132 pp (Dec 1980)

DP-1579

Key Words: Underground structures, Tunnels, Nuclear waste depositories, Rocks, Seismic waves, Earthquake response, Numerical analysis

The objectives of this generic study were to use numerical modeling techniques to determine under what conditions seismic waves generated by an earthquake might cause instability to an underground opening, or cause fracturing and joint movement that would lead to an increase in the permeability of the rock mass. Three different rock types (salt, granite, and shale) were considered as host media for the repository located at a depth of 600 meters. Special

material models were developed to account for the nonlinear material behavior of each rock type. The sensitivity analysis included variations in the in situ stress ratio, joint geometry, pore pressures, and the presence or absence of a fault. Three different sets of earthquake motions were used to excite the rock mass.

HARBORS AND DAMS

81-2541

Earthquake Analysis of Concrete Gravity Dams Including Dam-Water-Foundation Rock Interaction

A.K. Chopra and P. Chakrabarti

Univ. of California, Berkeley, CA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 363-383 (July-Aug 1981) 9 figs, 1 table, 19 refs

Key Words: Dams, Concretes, Earthquake damage, Interaction: structure-fluid

A general procedure for analysis of the response of concrete gravity dams, including the dynamic effects of impounded water and flexible foundation rock, to the transverse (horizontal) and vertical components of earthquake ground motion is presented. The problem is reduced to one in two dimensions, considering the transverse vibration of a monolith of the dam. The system is analyzed under the assumption of linear behavior for the concrete, foundation rock and water. The complete system is considered as composed of three substructures -- the dam, represented as a finite element system, the fluid domain, as a continuum of infinite length in the upstream direction, and the foundation rock region as a viscoelastic half-plane. The structural displacements of the dam are expressed as a linear combination of Ritz vectors, chosen as normal modes of an associated undamped dam-rock system. The effectiveness of this analytical formulation lies in its being able to produce excellent results by considering only a few Ritz vectors. The generalized displacements due to earthquake motion are computed by synthesizing their complex frequency responses using Fast Fourier Transform procedures. The stress responses are calculated from the displacements. An example analysis is presented to illustrate results obtained from this analytical procedure. Computation times for several analyses are presented to illustrate the effectiveness of the procedure.

81-2542

Simulation of Strong Earthquake Motion with Contained-Explosion Line Source Arrays, Report on Task 6: Feasibility of Earth Dam Testing

P.N. Agrawal and J.R. Bruce

SRI International, Menlo Park, CA, Rept. No. NSF/RA-800421, 50 pp (Sept 1980)
PB81-174096

Key Words: Dams, Dynamic tests, Earthquake simulation

This study explores the feasibility, scope, and cost of dynamic testing of earth and rock-filled dams using explosives to generate the required earthquake-like ground motions. It was concluded that the response of dams to high-level sustained earth shaking, representative of actual earthquakes, can be investigated with explosive array techniques. The dams should be of small to moderate size and should be constructed in a special field test site with moderately strong native soil (not rock). Earth shaking would be provided by contained-explosion arrays that can produce the high-level sustained motion in repeated tests without replacement. It was also concluded that application of strong motion from explosive arrays is not practical because of the risk of damage to the dam or its surroundings.

81-2543

Hydrodynamic and Foundation Interaction Effects in Earthquake Response of a Concrete Gravity Dam

A.K. Chopra and S. Gupta

Univ. of California, Berkeley, CA, ASCE J. Struc. Div., 107 (ST8), pp 1399-1412 (Aug 1981) 15 figs, 3 tables, 8 refs

Key Words: Dams, Concretes, Earthquake response

The displacement and stress responses are presented for Pine Flat Dam to the S69E component of the Taft ground motion only, and to the S69E and vertical components acting simultaneously. For each of these excitations, the response of the dam is analyzed four times corresponding to the following four sets of assumptions: (a) Rigid foundation, hydrodynamic effects excluded; (2) rigid foundation, hydrodynamic effects included; (3) flexible foundation, hydrodynamic effects excluded; and (4) flexible foundation, hydrodynamic effects included. Based on these results, the separate effects of dam-water interaction and dam-foundation rock interaction, and the combined effects of the two sources of interaction, on earthquake response of dams are investigated.

CONSTRUCTION EQUIPMENT

81-2544

Evaluation of Vibratory Rollers for Bomb Damage Repair

K.J. Knox

Engrg. and Services Lab., Air Force Engrg. and Services Ctr., Tyndall AFB, FL, Rept. No. AFESC/ESL-TR-80-43, 71 pp (Aug 1980)
AD-A096 534

Key Words: Compactors, Vibratory techniques, Vibratory tools, Airports

Four vibratory rollers in the 8.5 to 17-ton range were evaluated for use in bomb damage repair of airfields. The rollers were tested for their compaction ability on grade crushed limestone. After this initial testing the two most promising rollers were tested by repairing simulated bomb craters using 24-inch thick layers of crushed limestone compacted only from the surface. These repairs were tested with F-4 load-craft traffic.

81-2545

Effect of Barriers on Propagation of Construction Noise

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-113, 147 pp (Dec 1980)
PB81-166829

Key Words: Construction equipment, Noise barriers

The study reported is primarily concerned with investigating the effect of barriers on propagation of construction equipment noise and to examine the suitability of some of the more recent and widely used barrier theories. In addition, this study investigates the attenuation afforded by real sized cuttings and embankments with controlled loudspeaker sound source.

81-2546

Measurement and Prediction of Construction Plant Noise

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-112, 230 pp (Sept 1980)
PB81-166837

Key Words: Construction equipment, Noise prediction, Noise measurement

The purpose of this report is to summarize the results of a study concerned with the prediction and measurement of noise exposure levels from construction machinery on a site. The relevance of this subject is illustrated by reference to national and international standards and legislation. This study was consummated through the development and validation of prediction and measurement methodologies by considering the following topics: propagation characteristics of noise from stationary and mobile sources over realistic ground surfaces; directivity patterns of noise from construction equipment; transmission of loss characteristics by a building facade; and noise monitoring from construction sites.

81-2547

Assessment and Propagation of Noise from Conventional and 'Quiet' Pile Drivers

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-110, 184 pp (Sept 1980)
PB81-168866

Key Words: Pile drivers, Noise generation, Sound propagation

This report summarizes the results of a study aimed at defining some of the important basic characteristics of noise from conventional pile drivers, which are considered to be one of the most significant sources of noise annoyance in the community during civil engineering projects, and a range of pile driving devices which were either adapted or designed specifically to generate noise levels below those normally expected from conventional impact pile drivers. The parameters studied were noise levels, spectra and waveform shapes. This study has shown that recent legislation and other stimuli have resulted in a range of pile driving devices whose use, where circumstances permit, results in 10 to 40 dB(A) lower equivalent sound levels being generated by the extensively treated piling rigs as compared with the conventional untreated piling rigs, these reduced noise levels being equal to or less than that produced by other construction site noise sources. In addition, this study investigates the propagation characteristics of noise from pile drivers and also indicates how the noise from such a source is affected by the interposition of a barrier.

POWER PLANTS

81-2548

Noise Prediction for Fossil Fuel Power Plants

S. Shimode and H. Fujita

Mech. Engrg. Res. Lab., Hitachi, Ltd., Tsuchiura, Ibaraki, Japan, Noise Control Engrg., 17 (1), pp 22-29 (July-Aug 1981) 12 figs, 2 tables, 14 refs

Key Words: Fossil power plants, Electric power plants, Industrial facilities, Noise reduction

Noise control for large plants is one of the major pollution problems in Japan. Development of a technology for reliable prediction of the noise field for such plants is described. Characteristics of both sound sources and propagation paths are discussed in detail, mainly in reference to turbine housings of fossil fuel power plants. Comparison of the predicted noise field of a power plant with actual measurement showed good agreement and confirmed the usefulness of the prediction program developed.

81-2549

Response of a Themal Barrier System to Acoustic Excitation in a Gas Turbine Nuclear Reactor

W.S. Betts, Jr. and R.D. Blevins

General Atomic Co., San Diego, CA, Rept. No. CONF-810309-7, 11 pp (Nov 1980)
GA-A-16016

Key Words: Nuclear reactors, Thermal insulation, Acoustic excitation, Vibration analysis

A gas turbine located with a high-temperature gas-cooled reactor induces high acoustic sound pressure levels into the primary coolant (helium). This acoustic loading induces high cycle fatigue stresses which may control the design of the thermal barrier system. This study examines the dynamic response of a thermal barrier configuration consisting of a fibrous insulation compressed against the reactor vessel by a coverplate which is held in position by a central attachment fixture. The results of dynamic vibration analyses indicate the effect of the plate size and curvature and the attachment size on the response of the thermal barrier.

OFF-SHORE STRUCTURES

81-2550

Parameter Adjustment of a Model of an Offshore Platform from Estimated Eigenfrequencies Data

H. Natke and H. Schulze

Curt-Risch-Institut f. Schwingungs- und Messtechnik, Universität, Hannover, D-3000 Hannover 1, Fed. Rep. Germany, J. Sound Vib., 77 (2), pp 271-285 (July 22, 1981) 7 figs, 2 tables, 16 refs

Key Words: Off-shore structures, Drilling platforms, Parameter identification techniques, Damping coefficients

A full scale dynamic test which was incomplete because of rough seas and bad weather conditions and a computational model of the research platform "Nordsee" were the starting points of the work described in this paper. The transient excitation used in the test produced vibrations in the lower frequency range with certain identifiable eigenfrequencies and damping ratios. The identified eigenfrequencies were used as the basis for mass adjustment of the computational model. The computational model consists of a 176 degrees of freedom system, in which the flexible constraints and the virtual mass of water are neglected. The most uncertain data were the masses of the deck body. Parameter sensibility investigations, and a priori knowledge of the system and the test conditions led to an adjustment of the mass matrix partitioned corresponding to subsystems. The adjustment was carried out in a factorial global way, in respect to the defined subsystems. The result is an optimum model corresponding to the chosen loss function; the residuum used concerns the inverse eigenfrequency.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 2564, 2565, 2653, 2684, 2685, 2686)

81-2551

Analyzing Noise with Finite Elements

Machine Des., 53 (18), pp 148-153 (Aug 6, 1981) 1 ref

Key Words: Motor vehicle noise, Automobiles, Noise generation, Finite element technique

The use of the finite element technique to study noise propagation in intricate cavities is demonstrated by applying it in the analysis of an automobile compartment boom noise. Such noise is produced by cavity resonance excited by wind, loading engine vibration and road roughness. Results of the analysis show that seat shape has a significant effect on cavity resonance, suggesting that some design change may eliminate the booming phenomena.

81-2552

Reduction of Combustion Noise and Structural Improvement of Its Transmission Path in Diesel Engine Design

Y. Watanabe

Nissan Diesel Motor Co., Ltd., Ageo-shi, Japan, Intl. J. Vehicle Des., 2 (3), pp 276-288 (1981) 15 figs, 2 tables, 3 refs

Key Words: Trucks, Diesel engines, Noise reduction, Structural modification effects

In order to provide a quieter diesel engine as an essential component of low-noise trucks, a two-year investigation of combustion noise and engine structural analysis was carried out. Influences of various variables related to combustion noise were observed on a Vee type two-cylinder engine, and the variables which seemed to be effective for noise control were confirmed on a multi-cylinder engine. Structural analysis was advanced by using improved measuring techniques such as applications of laser holography, transfer function and F.F.T. Furthermore, the adoption of accelerated running simulation on an eddy-current dynamometer made noise evaluation possible in an engine operating condition that was close to the actual vehicular situation. The target figure of engine noise reduction, 2 to 4 dB(A), could be almost achieved by cylinder block structural modification and turbocharging or by increasing the compression ratio for N.A. engines. Engine noise control techniques found to be effective and their problems are also discussed.

81-2553

Analysis of Wheel Rail Force and Flange Force During Steady-State Curving of Rigid Trucks

H. Weinstock and R. Greif

Transportation Systems Ctr., Cambridge, MA, ASME Paper No. 81-RT-5

Key Words: Trucks, Interaction: rail-wheel

The wheel/rail forces and flange forces resulting from steady-state curve negotiation are developed through analysis of a rigid two-axle truck. The analysis provides closed form relations for estimating wheel/rail forces, flange forces, truck angle of attack and sliding conditions for this type of truck as a function of curve radius. The wheel profiles are modeled by conical wheel treads with vertical wheel flanges and flange friction effects are included. The theory used includes both linear and nonlinear creep.

81-2554

An Application of Stereoscopic Techniques Using Mobile High-Speed Cameras in Automotive Crash Simulation

A. Lozzi and J. Chapman

Dept. of Mech. Engrg., Univ. of Sydney, Australia, Intl. J. Vehicle Des., 2 (3), pp 299-307 (1981) 6 figs, 3 refs

Key Words: Collision research (automotive), Photographic techniques

Parallel axis stereophotography has been applied to record events of an automotive crash simulation. Two 16 mm, high frame rate, high acceleration cameras were used of the type developed for use on board military aircraft. The cameras travelled with the crashing vehicle, and were mounted on a rigid frame which was in turn attached to the floor pan of the vehicle. The crashes referred to here simulated car-to-pole side impacts. The cameras provided a stereoscopic record of events within the body shell's interior during the impact. Displacements and velocities of the anthropomorphic dummies seated in the body shell and of the intrusion caused by the pole, were determined using a single stereo photogrammetric method. Depth measurements were obtained with relative errors of about 1%, or 15 mm.

SHIPS

(See No. 2629)

AIRCRAFT

(Also see No. 2622)

81-2555

Structu.e-Borne Noise Prediction for a Single-Engine General Aviation Aircraft

J.F. Unruh

Southwest Res. Inst., San Anto.io, TX, J. Aircraft, 18 (8), pp 687-694 (Aug 1981) 13 figs, 1 table, 9 refs

Key Words: Aircraft noise, Structure-borne noise, Interior noise, Noise prediction, Finite element technique

The usefulness of a deterministic modeling procedure employing structural-acoustic finite-element formulations is investigated for the prediction of structure-borne interior noise. Analytical predictions are compared to normal mode, forced harmonic response, and engine-running experimental data obtained during ground tests of a single-engine general aviation aircraft. From these comparisons, the modeling procedures are shown to be sufficiently accurate for structure-borne interior noise prediction.

81-2556

An Optimization Method for the Determination of the Important Flutter Modes

E. Nissim and I. Lottati

Technion - Israel Inst. of Tech., Haifa, Israel, J. Aircraft, 18 (8), pp 663-668 (Aug 1981) 11 figs, 4 tables, 9 refs

Key Words: Aircraft, Flutter, Optimization

An optimization method for the determination of the dominant flutter modes is presented in this paper. The method is based on the minimization of the quadratic values of subdeterminants derived from the equations of motion. The effectiveness of the method is illustrated by seven numerical examples.

81-2557

Forced Backward Whirling of Aircraft Propeller-Engine Systems

S.H. Crandall and J. Dugundji

Massachusetts Inst. of Tech., Cambridge, MA, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 265-270, 5 figs, 4 refs

Key Words: Aircraft engines, Propellers, Propeller blades, Whirling

Transverse excitation of a light aircraft engine block by the sequential firing of the cylinders can excite a natural mode of vibration which involves backward whirling of the engine at the excitation frequency and propeller blade vibration at a frequency that is the sum of the excitation frequency and the engine speed. The phenomenon is explained in terms of a simplified model with only two non-trivial degrees of freedom.

81-2558

Crashworthiness Design Parameter Sensitivity Analysis

A.E. Tanner

Boeing Vertol Co., Philadelphia, PA, Rept. No. USAAVRADCOM-TR-80-D-31, 281 pp (Feb 1981) AD-A096 550

Key Words: Aircraft, Crash research (aircraft), Crashworthiness, Design techniques

This program investigated the relationships between aircraft weight, the level of crashworthiness in the design, and the cost and weight associated with crashworthiness elements of the design. Accident and research data were reviewed and actual aircraft designs were analyzed with respect to their levels of crashworthiness and potential improvements. Processing of the data yielded cost and weight curves for use in preliminary design. The curves provide the relationships between gross weight, mean empty weight, levels of crashworthiness, and selected design elements that contribute to crashworthiness for designs employing metallic or composite materials and having gross weights up to 50,000 pounds. Comparisons were made with the current ACAP analyses and results showed good agreement for the weight values and level of crashworthiness.

81-2559

Development of Advanced Techniques for Rotorcraft State Estimation and Parameter Identification

W.E. Hall, Jr., J.G. Bohn, and J.H. Vincent

Systems Control, Inc., (VT), Palo Alto, CA, Rept. No. NASA-CR-159297, 265 pp (Nov 1980) N81-19098

Key Words: Helicopters, Parameter identification techniques

An integrated methodology for rotorcraft system identification consists of rotorcraft mathematical modeling, three distinct data processing steps, and a technique for designing inputs to improve the identifiability of the data. These elements are as follows: (1) a Kalman filter smoother algorithm which estimates states and sensor errors from error corrupted data. Gust time histories and statistics may also be estimated; (2) a model structure estimation algorithm for isolating a model which adequately explains the data; (3) a maximum likelihood algorithm for estimating the parameters and estimates for the variance of these estimates; and (4) an input design algorithm, based on a maximum likelihood approach, which provides inputs to improve the accuracy of parameter estimates. Each step is discussed with examples to both flight and simulated data cases.

MISSILES AND SPACECRAFT

81-2560

Seismic Hazards Studies for Minuteman Missile Wings

J.C. Battis

Air Force Geophysics Lab., Hanscom AFB, MA, Rept. No. AFGL-TR-80-0293, 73 pp (Sept 9, 1980) AD-A096 720

Key Words: Missiles, Seismic response

Using standard methods of probabilistic seismic risk analysis, estimates of the seismic hazards for six Minuteman missile wings were evaluated. For each site, estimates of the site intensity, acceleration, velocity and displacement annual risk curves were made based on the historical seismicity within 1000 km of each site. Based on these curves, composite design response spectra for 10-, 100-, and 1000-year return period motions were calculated. Plots of the reported earthquake epicenters near each site were also generated. To conduct these studies, a new method for regional modification of peak acceleration attenuation functions was developed and is presented in the appendix to this report.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

(Also see No. 2568)

81-2561

Seismic Effectiveness of Tuned Mass Dampers

A.M. Kaynia, D. Veneziana, and J.M. Biggs

Massachusetts Inst. of Tech., Cambridge, MA, ASCE J. Struc. Div., 107 (ST8), pp 1465-1484 (Aug 1981) 11 figs, 1 table, 22 refs

Key Words: Tuned dampers, Single degree of freedom systems, Earthquake response, Buildings

Time history analysis of one degree of freedom systems with and without a tuned mass damper, subjected to a set of historical earthquakes, shows that the peak response ratio (ratio between the peak responses with and without damper) depends primarily on damping constants and on earthquake duration. The same analysis reveals that response ratio values are widely scattered and that the mean response ratio is underestimated by conventional stationary random vibration calculations. Improvement is obtained by considering response movement and broadening of the response spectral density function caused by the damper. Based on these considerations, a probabilistic model is developed that gives the distribution of peak response of buildings modified by addition of a tuned mass damper in terms of the same distribution for the unmodified structures.

81-2562

Avoiding Compromise in Engine Mounting

R. Racca

Barry Controls, Barry Wright Corp., Diesel Progress North American, 47 (8), pp 34-36 (Aug 1981)

Key Words: Mountings, Engine mounts

The author stresses the importance of proper mounting of an automobile engine, requiring a good understanding of the effect of dynamic loads on the engine. A dynamic analysis procedure is described.

81-2563

Design and Performance of Resonant-Cavity Parallel Baffles for Duct Silencing

P.T. Soderman

U.S. Army Research and Technology Lab., Ames Res. Ctr., Moffett Field, CA, Noise Control Engrg., 17 (1), pp 12-21 (July-Aug 1981) 18 figs, 1 table, 25 refs

Key Words: Silencers, Baffles, Ducts, Noise reduction

To control noise emission from large ducts, designers often choose some variation of parallel baffles filled with fibrous material. The acoustic performance of such silencers can be very good, but in severe environments they are susceptible to clogging, erosion and settling. There is an alternative – resonant-cavity parallel baffles. This type of baffle, either empty or with a thin absorbent lining pinned to an internal septum, is virtually immune to the above problems. An analytical and experimental study of resonant-cavity baffle silencers, including comparisons with fiberglass-filled baffles, is described.

81-2564

Fundamental Study on Semi-Actively Controlled Pneumatic Servo Suspensions for Rail Cars

K. Jindai, K. Kasai, K. Terada, Y. Kakehi, and F. Iwasaki

Japanese Natl. Railways, Tokyo, Japan, ASME Paper No. 81-RT-6

Key Words: Railroad cars, Suspension systems (vehicles), Semiactive isolation

Semi-actively controlled suspension systems were devised to reduce the vibrations of railroad passenger cars. Two

vertical and one lateral pneumatic servo cylinders were mounted parallel to the air springs on each truck. The acceleration signal of the car body above each cylinder was transferred independently to each controller, and the vertical and lateral controllers were adjusted to approximate the results of the optimum analysis of vertical vibration mode and yawing mode respectively.

81-2565

An Experimental Comparison Between Semi-Active and Passive Suspensions for Air-Cushion Vehicles

D. Hrovat and D.L. Margolis

Dept. of Mech. Engrg., Wayne State Univ., Detroit, MI, Intl. J. Vehicle Des., 2 (3), pp 308-321 (1981)
9 figs, 2 tables, 15 refs

Key Words: Suspension systems (vehicles), Ground effect machines, Dampers, Active damping, Semiactive isolation, Passive isolation

An experimental heave mode model of a tracked air cushion vehicle incorporating on-off semi-active (SA) damper suspension is described. Preliminary tests are conducted to assess the SA pneumatic damper characteristics. For identical sinusoidal ground inputs, the totally passive and on-off SA damping schemes are compared in terms of sprung mass vibration isolation properties. It is shown that the semi-active suspension offers significant advantages over the corresponding passive suspensions, while at the same time requiring only a small amount of control energy.

BLADES

81-2566

Further Studies of Bladed Disc Vibration: Effects of Packeting

D.J. Ewins

Imperial College of Science and Tech., London, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 97-102, 5 figs, 12 refs

Key Words: Blades, Turbomachinery, Tuning

Various studies made in recent years of the effects of blade mistuning on the vibration characteristics of turbomachine bladed disc assemblies have provided an understanding and explanation of many of the complex blade vibration phenomena observed under operating conditions. The concepts and techniques introduced in those studies have now been further developed to explore a new range of conditions; namely, where the 'mistuning' is no longer 'small' and is introduced deliberately. Such conditions prevail in bladed assemblies where the blades are grouped in packets either for convenience of assembly (as in steam turbines) or in order to induce a significant detuning of a certain assembly mode. The characteristics of such assemblies are described and their relationship to the corresponding properties of a symmetrical or tuned system established, since the computational effort required to analyze a packeted bladed disc is very much greater than for its continuously-shrouded counterpart.

81-2567

Stall Flutter of Linear Cascade in Compressible Flow

S. Kaji

Univ. of Tokyo, Tokyo, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 209-214, 6 figs, 5 refs

Key Words: Cascades, Jet engines, Fans, Flutter

Stall and non-stall bending mode flutter in high subsonic and supersonic flows is analyzed by the semi-actuator disc theory. Transonic two-dimensional cascade test data are used for the estimation of total pressure-loss change due to airfoil oscillation. Occurrence of 'resonance flutter' which is different from usual stall flutter is predicted. This flutter arises near the cascade resonance conditions for highly loaded cascades in high Mach number flows. Flutter boundaries obtained for subsonic flows and supersonic flows show quite different variations against the change in flow incidence. It is also shown that the direction of airfoil oscillation has a significant effect on flutter boundaries.

BEARINGS

(Also see Nos. 2506, 2527, 2659, and 2670)

81-2568

Gyroscopes with Ball Bearing Suspension

V.F. Zhuravlev and D.M. Klimov

Inst. for Problems in Mechanics, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 367-368, 1 fig, 3 refs

Key Words: Bearings, Ball bearings, Gyroscopes, Vibration analysis

Ball bearing suspension, which is often used in gyroscopic devices, constitutes a complex system of many elastic bodies (balls, rings, retainers). Special coordinates introduced allow calculation of the potential energy of gyroscopic systems taking into account all possible imperfections in ball bearings. The linear equations of motion of rotor in nonideal ball bearings derived define the spectrum and the level of vibration. The nonlinear equations allow discovery of a few fine phenomena (such as impossibility of exact balancing of rotor in nonideal ball bearings, etc.).

81-2569

Experimental Study of an Inter-Shaft Squeeze Film Bearing

J.B. Courage

Rolls Royce, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 375-380, 10 figs, 8 refs

Key Words: Bearings, Rolling contact bearings, Squeeze-film dampers

The application of squeeze films to the static outer races of rolling element bearings is now common practice in gas turbine engines. However many engines also feature inter-shaft bearings where the benefits of squeeze films could be equally significant. This paper describes an experimental program that has been carried out on a model twin shaft rig to evaluate the feasibility of such a device.

81-2570

Rubber Surface Squeeze Film

Y. Hori, T. Kato, and H. Narumiya

Dept. of Mech. Engrg., The Univ. of Tokyo, Bunkyo-ku, Tokyo, Japan, J. Lubric. Tech., Trans. ASME, 103 (3), pp 399-405 (July 1981) 13 figs, 10 refs

Key Words: Bearings, Squeeze film bearings, Elastomers, Low frequencies, High frequency excitation

Numerical solutions for the squeeze film problem, in which one of the surfaces is made of rubber and moves sinusoidally, are presented. Viscoelasticity and incompressibility of the rubber are taken into account in the numerical procedures. The solutions agree well with the experiments. Variation of the squeeze film shape with time is measured by the moiré topography. This will be one of the best methods for measuring the film thickness when the lubricating surface is made of soft materials like rubber.

81-2571

Some Damping and Stiffness Characteristics of Angular Contact Bearings under Oscillating Radial Load

T.L.H. Walford and B.J. Stone

Bearing Res. Ctr., Newark, Notts, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 157-162, 4 figs, 2 tables, 4 refs

Key Words: Bearings, Rolling contact bearings, Damping coefficients, Stiffness coefficients, Lubrication

Damping and stiffness measurements are presented for a pair of angular contact bearings which show damping increasing and stiffness decreasing as oil viscosity is reduced. A theoretical model is presented which indicates that the stiffness of the interfaces, between the races and the housing and shaft, is a very significant parameter and is the cause of the observed effect.

81-2572

Magnetic Bearings - A Novel Type of Suspension

G. Schweitzer and H. Ulbrich

Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 151-156, 10 figs, 12 refs

Key Words: Bearings, Magnetic bearings, Rotors

It is well known that a rotor can be supported without contact and without wear by suitable electromagnetic forces. The technical implementation of the basic idea, however, is still rather uncommon. By means of examples the state of the art and possible future trends of the theory and the application of magnetic bearings are demonstrated. One example, the full magnetic suspension of a centrifuge in a vacuum tube, is treated comprehensively.

81-2573

An Instrument for the Measurement of Long-Term

Variations of Vertical Bearing Alignments in Turbo-generators

A. Clapis, G.L. Lapini, and T. Rossini

Centro Informazioni Studi Esperienze, Milano, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 119-124, 10 figs, 3 refs

Key Words: Bearings, Turbogenerators, Alignment, Measurement techniques

A special instrument, called ADE, is described, purposely developed to measure the long-term variations of vertical bearing alignments in turbogenerators. The instrument is based on the communicating vessel principle. A proper number of interconnected cups containing mercury are attached to the machine supports. The liquid level variations in the cups, due to their vertical movements, are measured by proximity transducers fixed on the cup tops. The paper presents a summary of results from measurements by the ADE system on two large turbogenerators where the alignment changes have caused vibration problems.

81-2574

Generation of Squeal/Chatter in Water-Lubricated Elastomeric Bearings

A.I. Krauter

Tech. Dept., Shaker Research Corp., Ballston Lake, NY, J. Lubric. Tech., Trans. ASME, 103 (3), pp 406-413 (July 1981) 7 figs, 3 tables, 5 refs

Key Words: Bearings, Elastomeric bearings, Chatter

This paper presents results from an investigation concerned with vibrational characteristics of compliant-layer water-lubricated bearings. An experimental apparatus emulates the dynamic interactions between the propeller shaft and a water-lubricated elastomeric bearing stave. A computer model predicts the squeal tendency of the experimental apparatus. Correlations are obtained by using the apparatus to verify the predicted squeal tendency. Utilizing the computer model, the effects of varying system parameters on squeal/chatter are determined quantitatively. From the results obtained, it is found that the slope of the friction-speed curve and the effective structural damping are the most important parameters. It is concluded that the essential features of squeal/chatter have been identified and that the phenomenon can be modeled analytically.

81-2575

Dynamically Tuned Gyroscopes and Their Spin Axis Bearings

D.G. Bonfield and D.J. Haines

Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 327-332, 3 figs, 3 tables, 5 refs

Key Words: Bearings, Gyroscopes, Tuning

British Aerospace work on rotor restraint and vibration problems which can limit dynamically tuned gyroscope performance is discussed. The work has resulted through careful design, development and control of critical parts in a series of dynamically tuned gyroscopes to meet missile, aircraft and ship guidance requirements. Gyro rotors mounted on a single gimbal and subject to excitation may now be trimmed to a drift rate of less than 0.1°/hour. For other applications a double gimballed, two axis free rotor unit has been developed in which a number of torsion flexing hinged elements are arranged in a manner similar to two interlaced Hooke's joints but where the freely pivoting hinges of the latter are replaced by torsion cross leaf springs and the intermediate frame members of the couplings act as dynamic gimbals. Drift rates of much less than the above are achieved with these units.

81-2576

Effects of Vibrations Generated by Spin Axis Bearings on Gyroscopic Northfinding Equipment

B.T. Trayner

Stevenage Div., British Aerospace Dynamics Group, Stevenage, Herts SG1 2DA, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 347-352, 4 figs, 1 table, 3 refs

Key Words: Bearings, Gyroscopes, Beat frequency

The paper outlines a particular problem associated with the production of a first generation northfinder due to beating between the angular velocity of the two cages in the spin axis system. This beat frequency was troublesome when very low (with a period of up to 200 seconds) and very low values appeared with an occurrence rate which was higher than would be predicted by the bearing geometry. The practical solution to the problem which was adopted is given and the influence that this had on the design of a second generation northfinder is discussed.

81-2577

On the Steady State and Dynamic Performance Characteristics of Floating Ring Bearings

C.-H. Li and S.M. Rohde
Mech. Res. Dept., General Motors Res. Labs., Warren, MI, J. Lubric. Tech., Trans. ASME, 103 (3), pp 389-397 (July 1981) 18 figs, 13 refs

Key Words: Bearings, Floating ring journal bearings, Journal bearings, Periodic response

An analysis of the steady state and dynamic characteristics of floating ring journal bearings has been performed. The stability characteristics of the bearing, based on linear theory, are given. The transient problem, in which the equations of motion for the bearing system are integrated in real time was studied. The effect of using finite bearing theory rather than the short bearing assumption was examined. Among the significant findings of this study is the existence of limit cycles in the regions of instability predicted by linear theory. Such results explain the superior stability characteristics of the floating ring bearing in high speed applications. An understanding of this nonlinear behavior serves as the basis for new and rational criteria for the design of floating ring bearings.

81-2578

The Effects of Unbalance on Stability and Its Influence on Non-Synchronous Whirling

R.H. Bannister and J. Makdissy
Cranfield Inst. of Tech., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 395-400, 12 figs, 4 refs

Key Words: Bearings, Journal bearings, Hydrodynamic excitation, Whirling, Nonsynchronous vibration

When investigating the behavior of hydrodynamic journal bearings, the criteria for instability is usually defined as a single line on the stability map and no attempt is made to explain the possible working limits between the stable and unstable zones. The work presented is intended as an introduction, explaining the transitional stages of instability and suggests how to estimate the severity of instability by pattern recognition. The influence of nonlinearity of the oil film is also demonstrated, by staging the onset of instability and noting the stabilizing influence made to the bearing for varying magnitudes of unbalance force.

81-2579

On the Dynamic Behaviour of Gyroscopic Systems that Include Oil Lubricated Journal Bearings

H. McCallion and P.M. Ware
Dept. of Mech. Engrg., Univ. of Canterbury, Christchurch, New Zealand, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 133-138, 6 figs, 7 refs

Key Words: Bearings, Journal bearings, Rotors, Shafts, Gyroscopes

Results are reported from a theoretical study into the influences of a number of system parameters on the stability of a family of systems in conical motion. Each member was comprised of a massive rotor, an elastic shaft and a journal bearing. Small oscillations about a steady running position were studied by linearizing the oil film characteristics and it was found that the higher natural frequency could be unstable even when its value was as high as 0.8 times the spin velocity of the shaft. Whirl velocities greater than 0.5 times the spin velocity are not usually associated with oil whip. It is also shown by numerical simulation that some members of this family of systems may be stable at low amplitudes and unstable at high amplitudes and vice versa.

81-2580

Identification of Journal Bearing Coefficients Using a Pseudo-Random Binary Sequence

I.U. Dogan, J.S. Burdess, and J.R. Hewit
Dept. of Mech. Engrg., Univ. of Newcastle upon Tyne, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 277-281, 4 figs, 8 refs

Key Words: Bearings, Journal bearings, Parameter identification techniques, Stochastic processes, Spectrum analysis

A stochastic identification technique based upon spectral analysis has been developed to provide a dynamic model of a journal bearing. An outline of the basic theory is given and the results of experimental work carried out on a laboratory journal bearing are described. Direct and cross transfer functions are derived from the bearing response to pseudo binary excitation and the bearing coefficients determined by optimally fitting theoretical transfer functions to the experimental results.

81-2581

Experimental and Analytical Research on a Full Scale Turbine Journal Bearing

G. Diana, D. Borgese, and A. Dufour

Mechanics of Machinery Inst., Milan, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 309-314, 9 figs, 1 table, 7 refs

Key Words: Bearings, Journal bearings, Turbines

The purpose of the research is to determine the statistical and dynamical behavior of a large sized lubricated bearing. A testing campaign has been carried out on a full scale bearing of a low pressure turbine in a 320 MW turbo alternator. The results are compared with analytical ones.

81-2582

Experiments on the Dynamic Characteristics of Large Scale Journal Bearings

S. Hisa, T. Matsuura, and T. Someya
Turbine Works, Toshiba Corp., Yokohama, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 223-230, 9 figs, 1 table, 6 refs

Key Words: Bearings, Journal bearings, Stiffness coefficients, Damping coefficients

The dynamic characteristics of large scale journal bearings were studied with special reference to the 20-in. diameter load on pads bearing and 32-in. diameter elliptical bearing. Experiments were carried out in a full scale bearing test rig in which static loads up to 80 tons and dynamic loads between ±3 and ±9 tons with the frequency ranging from 20 Hz to 60 Hz can be imposed upon the test bearing. Stiffness and damping coefficients in both laminar and turbulent regime were obtained, and some features of the dynamic characteristics of the two bearings are discussed. It is also suggested that the outlet oil temperature should be used as the representative temperature for the oil film viscosity. Coefficients are applied for the unbalance response analysis of large steam turbogenerator rotors in service.

81-2583

Identification of Stiffness and Damping Coefficients of Journal Bearings by Means of the Impact Method

R. Nordmann and K. Schöllhorn
Technische Hochschule Darmstadt, Fed. Rep. Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 231-238, 12 figs, 4 refs

Key Words: Bearings, Journal bearings, Stiffness coefficients, Damping coefficients, Parameter identification techniques, Impact tests

This paper describes an identification method to find system parameters of rotating machines, especially the bearing stiffness and damping coefficients. A rigid rotor, running in journal bearings, is excited by a hammer (pulse testing). Input signals (forces) and output signals (displacements of the rotor) are transformed into the frequency domain and the complex frequency response functions are calculated. Analytical frequency response functions, which depend on the bearing coefficients, are fitted to the measured functions. Stiffness and damping coefficients are the results of an iterative fitting process. Results for a cylindrical bearing are presented and compared with coefficients from other authors.

81-2584

Analytical Nonlinear Bearing Calculations Using a Variational Approach

L.E. Barrett, P.E. Allaire, and D.F. Li
Dept. of Mech. and Aerospace Engrg., Univ. of VA, Charlottesville, VA, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 247-252, 3 figs, 9 refs

Key Words: Bearings, Journal bearings, Variational methods

A solution to the variational equivalent of Reynolds equation for finite length plain cylindrical and segmented journal bearings is presented. An infinite trigonometric series expansion of the pressure field is assumed and the expansion coefficients are found by minimization of the variational principle. The method is intended for use in nonlinear time transient simulations of rotor-bearing systems where finite difference and finite element solutions are computationally too costly to be employed.

81-2585

Estimation of Seal Bearing Stiffness and Damping Parameters from Experimental Data

S.B. Childs, D.W. Childs, and J. Dresden
Texas A&M Univ., College Station, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Church-

ill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 175-180, 4 figs, 1 table, 19 refs

Key Words: Test stands, Measurement techniques, Rotors, Seals, Bearings, Stiffness coefficients, Damping characteristics

A test stand has been constructed to measure displacements and forces related to high performance rotors and their bearings and seals. An existing code for solution of boundary value problems in ordinary differential equations is used to estimate the stiffness and damping parameters for the rotor-bearing-seal. Test results indicate that the test stand and method give a more reliable and economical means of estimating these coefficients than other published means.

GEARS

(Also see Nos. 2656, 2657, 2671, 2676)

81-2586

Vibration Spectra from Gear Drives

A.W. Lees and P.C. Pandey

Scientific Services Dept., Ratcliffe-on-Soar, Nottingham, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 103-108, 4 figs, 3 refs

Key Words: Gear drives, Vibration response spectra

Manufacturing errors are known to have a major influence on the dynamic performance and integrity of gear drives. For example, in large pulverizing mill drive trains, some of the low-speed gears are so heavily loaded that they suffer significant wear quite early in life. Usually there is enough metal in the teeth to give many years' service but profile errors result in increased dynamic gear tooth forces in the worn gears, as well as in the other gears in the drive train. It is important to know the magnitude of these increased forces so that, if necessary, remedial action can be taken to avoid premature failure. The complete shaft/bearing system is analyzed as a set of segments, each segment terminated at a gear mesh. Equations of constraint are then applied which impose on the system an amplitude-controlled vibration (which may be both flexural and torsional). It is shown how this leads to a response which contains frequencies that are orders of shaft speed, as well as frequencies which are independent of shaft speed. Good agreement is observed between vibration spectra taken from operational plant items and spectra predicted theoretically.

COUPLINGS

81-2587

The Selection of Couplings for Engine Test Beds

C.A. Beard

Ricardo Consulting Engineers, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 115-118, 3 figs, 2 refs

Key Words: Couplings, Test facilities, Engines, Combustion engines, Whirling, Torsional response

Problems exist in the selection of couplings for high speed internal combustion engine testbeds. These are reviewed briefly and an approximate, but safe, method for selecting a suitable coupling for particular duties is given. Reference is made to the need to check whirling characteristics as well as the purely torsional aspects. A number of practical installation requirements are referred to briefly.

FASTENERS

81-2588

Vibration Aspects of Rolling Mill Horizontal Drives with Reference to Recent Coupling Development

C. Patterson, J.L. Wearing, and J.D. Fletcher

Dept. of Mech. Engrg., Univ. of Sheffield, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 315-320, 5 figs, 2 tables, 6 refs

Key Words: Joints (junctions), Universal joints, Metal working, Torsional vibration, Translational response, Vibration control

This paper presents a critical survey of the development and increasing industrial use of Hooke (Cardan) joints where high torques are involved. Their use in rolling mill horizontal drives in the metal processing industry is discussed as a specific example and the effects on operating and vibratory behavior identified. The use of these couplings reduces translational and torsional vibratory motion in the mill drives resulting in reduced maintenance, wear and power consumption and improved product quality.

81-2589

Lap Splices in Reinforced Concrete under Impact

T. Rezansoff, J.O. Jirsa, and J.E. Breen
Dept. of Civil Engrg., Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada, ASCE J. Struc. Div., 107 (ST8), pp 1611-1628 (Aug 1981) 9 figs, 4 tables, 10 refs

Key Words: Bonded structures, Joints (junctions), Beams, Concretes, Reinforced concrete, Impact response

The performance of lap splices subjected to impact loading was studied and compared with that of splices under static loading. Nineteen specimens were tested under impact loading, with failure produced in either one impact, in the three to five impacts of incrementally increasing magnitude, or under either unidirectional or reversed cycling of the impact load. Analytical studies were carried out to help evaluate the experimental data. The impact moment capacity of the splices tested was equal to or greater than the static moment capacity.

LINKAGES

81-2590

The Application of Finite Element Methods to the Dynamic Analysis of Flexible Spatial and Co-Planar Linkage Systems

W. Sunada and S. Dubowsky
School of Engrg. and Applied Science, Univ. of California, Los Angeles, CA, J. Mech. Des., Trans. ASME, 103 (3), pp 643-651 (July 1981) 13 figs, 2 tables, 24 refs

Key Words: Linkages, Finite element technique, NASTRAN (computer programs), Component mode synthesis

An analytical method is presented for the dynamics of spatial mechanisms containing complex-shaped, flexible links with application to both high-speed industrial machines and robotic manipulators. Existing NASTRAN-type finite element structural analysis programs are combined with 4 x 4 matrix dynamic analysis techniques and Component Mode Synthesis coordinate reduction to yield a procedure capable of analyzing complex, nonlinear spatial mechanisms with irregularly shaped links in great detail, yet producing a system of equations small enough for efficient numerical integration. The method is applied to two examples.

VALVES

81-2591

Pressure Relief Valve Noise Attenuation

T.R. Bordelon and J.F. Etherington
Dresser Industries, Alexandria, LA, ASME Paper No. 81-PVP-38

Key Words: Valves, Pressure regulators, Noise reduction

Noise sources related to safety relief valve discharge piping systems are identified. A brief discussion of noise terminology is presented in conjunction with a method of estimating the magnitude of noise sources. Methods to reduce noise levels along with silencer selection and installation guidelines are presented.

SEALS

(Also see No. 2585)

81-2592

Labyrinth Seal Effects on Rotor Whirl Instability

B.T. Murphy and J.M. Vance
Dept. of Mech. Engrg., Texas A&M Univ., College Station, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 369-373, 3 figs, 1 table, 6 refs

Key Words: Seals, Rotors, Whirling

The destabilizing effect of labyrinth seals on rotor whirl was first identified by Alford in 1965. Alford's analytical model included the assumption of choked flow at both the inlet and outlet blades of a two blade seal. This paper points to other information which indicates that choked flow can exist only at the exit blade. Under the latter assumption an analysis is performed for a multiblade labyrinth seal. The effects on rotor response and whirl stability are discussed.

81-2593

Flow Induced Spring Constants of Labyrinth Seals

H. Benckert and J. Wachter
Institut fuer Thermische Stroemungsmaschinen, Univ. of Stuttgart, Stuttgart, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill

College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 53-63, 13 figs, 14 refs

Key Words: Rotors, Seals, Compressors, Fluid-induced excitation

Self-excited rotor vibrations which are a function of output are being increasingly observed in high-performance turbomachinery, in particular high-pressure compressors. A possible source of these rotor instabilities lies in the dynamic behavior of the labyrinth seals. Information on flow-induced spring constants in these types of machines is necessary to ahcieve a more effective vibration analysis. The work presented deals with the force patterns in eccentric-mode labyrinth seals, the exciting lateral force components perpendicular to the rotor displacement plane, and the restoring force components in this plane. The discussion includes the effects of operational parameters such as the differential pressure ratio, speed and entry flow conditions as well as the geometry of the labyrinth on the spring characteristics of these components. Stability calculations for a high-pressure steam turbine and a radial compressor demonstrate the application of the results.

81-2594

Elastohydrodynamic Lubrication of Offset O-Ring Rotary Seal

M.S. Kaisi

Kaisi Engrg., Inc., Houston, TX, J. Lubric. Tech., Trans. ASME, 103 (3), pp 414-427 (July 1981) 27 figs, 21 refs

Key Words: Shafts, Seals, Elastomeric seals, Lubrication, Elastohydrodynamic properties

A fundamental research into the lubrication mechanism and operation of a new type of rotary shaft seal has been conducted. Optical interference technique was successfully used to study the film profiles with optically smooth elastomer seals. Elastohydrodynamic lubrication was found to exist over a wide range of operating conditions. A study of the other performance variables for the Offset-Seal define its useful application range to be between the Packing-Gland and Face-Seal.

81-2595

An Analysis of Mechanical Face Seal Vibrations

I. Etsion and Y. Dan

Dept. of Mech. Engrg., Technion, Haifa, Israel, J. Lubric. Tech., Trans. ASME, 103 (3), pp 428-435 (July 1981) 4 figs, 21 refs

Key Words: Seals, Rings, Vibration analysis

The motion of a flexibly mounted ring in a mechanical face seal is described in its major three degrees of freedom. The equations of motion include fluid film as well as flexible support forces and moments. These equations are linearized using small perturbation analysis. It is shown that for small perturbation the axial motion is uncoupled with the two angular ones and is always stable. A condition for angular stability is derived relating seal operating conditions to its geometry and other design parameters.

81-2596

Analysis of High Pressure Oil Seals for Optimum Turbocompressor Dynamic Performance

R.G. Kirk and J.C. Nicholas

Turbo Machinery Group, Ingersoll-Rand Co., Phillipsburg, NJ, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 125-131, 10 figs, 3 refs

Key Words: Seals, Turbocompressors, Rotors, Computer-aided techniques, Vibration analysis

The influence of high pressure oil seal rings on the response and stability of turbocompressors is discussed and a method of analysis presented which can be automated for digital computer simulation. The method of analysis is summarized for calculation of the dynamic characteristics including the influence of sealing pressure and thermal equilibrium of the oil film. The results of automated dynamic simulations of turbocompressor systems, including the influence of oil seals, are presented for both steady-state response and dynamic stability. The advantages and disadvantages of the oil seals with regard to vibration performance are discussed for supercritical operation.

STRUCTURAL COMPONENTS

BARS AND RODS

81-2597

Apparent Complex Young's Modulus of a Longitudinally Vibrating Viscoelastic Rod

T. Pritz

Central Research and Design Inst. for Silicate Industry, 1034 Budapest, Becsi ut 126/128, Hungary, J. Sound Vib., 77 (1), pp 93-100 (July 8, 1981) 5 figs, 1 table, 19 refs

Key Words: Rods, Viscoelastic properties, Wave propagation, Longitudinal vibration

Longitudinal vibration of a viscoelastic rod with a finite lateral dimension is theoretically analyzed on the basis of the approximate Love theory. The frequency range where the Love theory gives good approximation and its accuracy in that range are determined. The theory predicts that the wave propagation in a viscoelastic rod is not governed solely by the complex Young's modulus of the material at higher frequencies, due to the lateral motion, but by its apparent value. It is shown that the apparent dynamic Young's modulus is smaller and the apparent loss factor is larger than the corresponding actual values for the material. The differences between the apparent and actual values depend on the lateral dimension to wavelength ratio and on the complex elastic constants as well.

BEAMS

(Also see No. 2511)

81-2598

Dynamic Response of a Beam with a Geometric Nonlinearity

S.F. Masri, Y.A. Mariamy, and J.C. Anderson

Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 404-410 (June 1981) 9 figs, 17 refs

Key Words: Beams, Geometric effects, Viscous damping, Harmonic excitation, Random excitation

Analytical and experimental studies were made of the dynamic response of a system with a geometric nonlinearity, which is encountered in many practical engineering applications. An exact solution was derived for the steady-state motion of a viscously damped Bernoulli-Euler beam with an unsymmetric geometric nonlinearity, under the action of harmonic excitation. Experimental measurements of a mechanical model under harmonic as well as random excitation verified the analytical findings. The effect of various dimensionless parameters on the system response was determined.

81-2599

Beam Models for Predicting Dynamic Elastic Response

V.H. Neubert and V.P. Rangaiah

Pennsylvania State Univ., State College, PA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 355-361 (July-Aug 1981) 5 figs, 2 tables, 5 refs

Key Words: Beams, Bernoulli-Euler method, Natural frequencies, Transient response, Lumped parameter method

Further investigation of the three-parameter lumped mass model for the prediction of natural frequencies and transient response of Bernoulli-Euler clamped-clamped beams has resulted in a revised model, which is slightly superior to the original model as it is applicable over a wider frequency range.

81-2600

Static and Dynamic Analyses of Thick Beams of Bimodular Materials

C.W. Bert and A.D. Tran

School of Aerospace, Mech. and Nuclear Engrg., Univ. of Oklahoma, Norman, OK, Rept. No. OU-AMNE-81-7, 68 pp (July 1981) 21 figs, 14 tables, 58 refs

Key Words: Beams, Timoshenko theory, Transient response, Asymmetry, Stiffness

This report deals with the behavior of beams made of bimodular materials, which have one value for the elastic modulus in tension and another in compression. The transfer-matrix approach is used to investigate the small-deflection response to a variety of loadings, both static and transient. The beam is modeled as a Timoshenko beam; i.e., both transverse shear deformation and rotatory inertia are included. Within each field element, provision is made for a neutral-surface position (locus of points having a zero value for the total axial normal strain) that may vary linearly with axial position within the element. The report consists of two distinct parts: Part I covers the static behavior, while Part II deals with transient dynamic behavior.

CYLINDERS

(Also see Nos. 2536, 2629, 2673)

FRAMES AND ARCHES

81-2601

Post-Elastic Dynamics of Three-Dimensional Frames

A.G. Gillies and R. Shepherd

Beca, Carter, Hollings & Ferner, Consulting Engrs., Wellington, New Zealand, ASCE J. Struc. Div., 107 (ST8), pp 1485-1501 (Aug 1981) 10 figs, 1 table, 4 refs

Key Words: Framed structures, Concretes, Reinforced concrete, Seismic design, Earthquake resistant structures

The time-history response of a three-dimensional reinforced concrete frame structure to concurrent earthquake ground motions is analyzed. Yielding is allowed in both beams and columns by a series of yield surface options selected according to the principal structural actions of the component elements. Comparisons between the behavior patterns arising from unidirectional and concurrent earthquake loading indicate that the nonlinear response predicted by a full three-dimensional analysis is significantly different from the response based on a planar frame idealization. Concurrent loading causes asymmetric distribution of yield as a result of the interaction of the orthogonal displacement components, and this gives rise to an eccentricity between the mass and the instantaneous center of stiffness at some levels in the building. Nominally symmetric buildings can develop torsional responses in moderate earthquakes.

PANELS

(Also see No. 2650)

81-2602

Sound Transmission through Elastically Supported Sandwich Panels into a Rectangular Enclosure

S. Narayanan and R.L. Shanbhag
Dept. of Appl. Mechanics, Indian Inst. of Tech., Madras, India, J. Sound Vib., 77 (2), pp 251-270 (July 22, 1981) 5 figs, 3 tables, 14 refs

Key Words: Panels, Sandwich structures, Viscoelastic core-containing media, Enclosures, Sound transmission

Sound transmission through viscoelastic sandwich panels into rectangular enclosures is investigated in the low frequency range (0 - 1000 Hz). Both harmonic and stationary random external pressure fields are considered. Two opposite edges of the plate are simply supported while the other two edges are elastically supported. A forced damped normal mode analysis is used for response calculations. Numerical results are presented for different parameters of the viscoelastic core.

PLATES

81-2603

Elastic Instability of a Heated Annular Plate under Lateral Pressure

J. Tani
Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 399-403 (June 1981) 7 figs, 16 refs

Key Words: Plates, Annular plates, Thermal excitation

On the basis of the dynamic version of the nonlinear von Karman equations, a theoretical analysis is performed on the elastic instability of a uniformly heated, thin, annular plate which has suffered a finite axisymmetric deformation due to lateral pressure. The linear free vibration problems around the finite axisymmetric deformation of the plate are solved by a finite-difference method. By examining the frequency spectrum with various asymmetric modes, the critical temperature rise under which the axisymmetric deformation becomes unstable due to the bifurcation buckling is determined, which is found to jump up to 7.2 times within a range of very small lateral pressure.

81-2604

Vibration of Thick Rectangular Plates of Bimodulus Composite Material

C.W. Bert, J.N. Reddy, W.C. Chao, and V.S. Reddy
School of Aerospace, Mech. and Nuclear Engrg., The Univ. of Oklahoma, Norman, OK, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 371-376 (June 1981) 6 tables, 20 refs

Key Words: Plates, Rectangular plates, Finite element technique, Small amplitudes

A finite-element analysis is carried out for small-amplitude free vibration of laminated, anisotropic, rectangular plates having arbitrary boundary conditions, finite thickness shear moduli, rotatory inertia, and bimodulus action (different elastic properties depending upon whether the fiber-direction strain is tensile or compressive). The element has five degrees of freedom, three displacements and two slope functions, per node. An exact closed-form solution is also presented for the special case of freely supported single-layer orthotropic and two-layer, cross-ply plates. This solution provides a benchmark to evaluate the validity of the finite-element analysis. Both solutions are compared with numerical results existing in the literature for special cases (all for ordinary, not bimodulus, materials), and good agreement is obtained.

81-2605

Nonlinear Theory for Flexural Motions of Thin Elastic Plate, Part 1: Higher-Order Theory

N. Sugimoto

Dept. of Mech. Engrg., Faculty of Engrg. Science, Osaka Univ., Toyonaka, Osaka, Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 377-382 (June 1981) 21 refs

Key Words: Plates, Flexural vibration

This paper develops a comprehensive higher-order theory for flexural motions of a thin elastic plate, in which the effect of finite thickness of the plate and that of small but finite deformation are taken into account. Based on the theory of nonlinear elasticity for a homogeneous and isotropic solid, the nonlinear equations for the flexural motions coupled with the extensional motions are systematically derived by the moment asymptotic expansion method. Denoting by ϵ the ratio of the thickness of the plate to a characteristic wavelength of flexural motions, an order of characteristic deflection is assumed to be ϵ^2 and that of a characteristic strain ϵ^3. The displacement and stress components are sought consistently up to the next higher-order terms than those in the classical theory.

81-2606

Nonlinear Theory for Flexural Motions of Thin Elastic Plate, Part 2: Boundary-Layer Theory Near the Edge

N. Sugimoto
Dept. of Mech. Engrg., Faculty of Engrg. Science, Osaka Univ., Toyonaka, Osaka, Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 383-390 (June 1981) 13 refs

Key Words: Plates, Flexural vibration, Elastic properties, Boundary layer excitation

This paper deals with, as a continuation of Part 1 of this series, the boundary-layer theory for flexural motions of a thin elastic plate. In the framework of the higher-order theory developed in Part 1, three independent boundary conditions at the edge of the plate are too many to be imposed on the essentially fourth order differential equations. To overcome this difficulty, a boundary layer appearing in a narrow region adjacent to the edge is introduced. Using the matched asymptotic expansion method, uniformly valid solutions for a full plate problem are sought. The boundary-layer problem consists of the torsion problem and the plane problem. Three types of the edge conditions are treated, the built-in edge, the free edge, and the hinged edge. Depending on the type of edge condition, the nature of the boundary layer is characterized. After solving the boundary-layer problem, "reduced" boundary conditions relevant to the higher-order theory are established.

SHELLS

(Also see No. 2673)

81-2607

Dynamic Stability of Truncated Conical Shells under Pulsating Torsion

J. Tani
Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 391-398 (June 1981) 7 figs, 1 table, 13 refs

Key Words: Shells, Conical shells, Torsional excitation, Periodic excitation

The dynamic stability of clamped, truncated conical shells under periodic torsion is analyzed by the Galerkin method in conjunction with Hsu's results. The instability regions of practical importance are clarified for relatively low frequency ranges. Numerical results indicate that under the purely periodic torsion only the combination instability region exists but that with an increase in the static torsion the principal instability region becomes most significant. The relative openness of the instability regions is found to depend sensitively on the circumferential phase difference of two vibration modes excited simultaneously at the resonance with the same circumferential wave number.

81-2608

Vibrations of Cylindrical Shells with Time-Dependent Boundary Conditions

S.Y. Lu
Univ. of Florida, Gainesville, FL, ASME Paper No. 81-PVP-21

Key Words: Shells, Cylindrical shells, Time-dependent parameters, Boundary condition effects

Dynamic edge effects on the vibrations of elastic shells are studied by separation of variables. The linear nonhomogeneous differential equations are satisfied by separating the displacement functions into two parts: a free vibration solution and a particular solution which satisfies the time-dependent boundary conditions. The theory is applied to the solution of the clamped-clamped cylinder with oscillating edges.

81-2609

The Effects of Wall Discontinuities on the Propagation of Flexural Waves in Cylindrical Shells

C.R. Fuller

Inst. Sound Vib. Res., Southampton Univ., UK, Rept. No. ISVR-TR-106, 64 pp (Mar 1980)
PB81-168858

Key Words: Shells, Cylindrical shells, Pipes (tubes), Vibration isolation, Discontinuity-containing media, Flexural waves

The transmission of flexural type waves through various discontinuities in the walls of cylindrical shells is investigated. Theoretical curves of transmission loss are obtained for different circumferential wavenumbers and wave types, as functions of frequency. Material stiffness and extensional phase speed, together with the relationship between radial vibration amplitude and total wave power of propagation, are important factors which are found to strongly influence wave transmission through discontinuities. Some practical results useful for predicting the performance of typical pipe isolators (in vacuo) are obtained.

81-2610

Wave Propagation in a Thin-Walled Viscoelastic Tube Due to Sudden Release of External Loading

T.B. Moodie, J.B. Haddow, and R.J. Tait
Dept. of Mathematics, Univ. of Alberta, Edmonton, Alberta, Canada, Intl. J. Engrg. Sci., 19 (11), pp 1441-1448 (1981) 2 figs, 4 refs

Key Words: Shells, Cylindrical shells, Tubes, Viscoelastic properties

An approximate thin shell theory is used to analyze the dynamic response of an axially constrained incompressible viscoelastic cylindrical tube, due to the sudden release of an axially symmetric uniformly distributed line loading. It is assumed that the tube is sufficiently long that end effects can be neglected. The analysis is based on the linear theory of viscoelasticity and a standard viscoelastic material is considered. Numerical results are obtained by the Fast Fourier Transform algorithm and are presented graphically for a wide range of parameter values.

81-2611

Damage Characteristics of an Infinite Cylindrical Shell Excited by a Transient Acoustic Wave

T.L. Geers and C.L. Yen
Palo Alto Res. Lab., Lockheed Missiles and Space Co., Inc., Palo Alto, CA, Rept. No. LMSC-D686495, 29 pp (Mar 1981)
AD-A096 686

Key Words: Shells, Cylindrical shells, Submerged structures, Transient response, Sound waves, Interaction: structure-fluid

An analytical/computational technique previously developed for determining the geometrically and constitutively non-linear response of a submerged, infinite cylindrical shell to a transverse, transient acoustic wave is used to study the damage behavior of the shell. Incident waves of rectangular pressure-profile are considered, nonlinear transient response computations are performed, and damage results are described in terms of iso-damage curves based on extensional set strain. Results generated through the use of the doubly asymptotic approximation for treatment of the fluid-structure interaction differ appreciably from their exact counterparts.

81-2612

Modal Response of Circular Cylindrical Shells with Structural Damping

A.W. Leissa and K.M. Iyer
Dept. of Engrg. Mechanics, Ohio State Univ., Columbus, OH, J. Sound Vib., 77 (1), pp 1-10 (July 8, 1981) 4 figs, 7 tables, 12 refs

Key Words: Shells, Circular shells, Cylindrical shells, Periodic excitation, Damping effects, Hysteretic damping, Modal analysis

Although a vast literature exists dealing with the free vibration of circular cylindrical shells, relatively little can be found for the problem of dynamic response due to sinusoidally varying exciting forces, especially when damping exists. In the present work the response of a shell subjected to a sinusoidal radial pressure is studied, when the pressure has the same distribution as the normal mode shape. Structural (hysteresis) damping is considered. For a unit amplitude of exciting pressure, the lowest frequency modes are found to yield the largest resonant response. Because of a small amount of mode coupling, the peak amplitudes are found to be not quite inversely proportional to the strength of the damping, and there is a slight shift in the locations of the resonant peaks.

81-2613

The Effect of Viscosity on Free Vibrations of Submerged Fluid-Filled Spherical Shells

T.C. Su
Dept. of Civil Engrg., Texas A&M Univ., College Station, TX, J. Sound Vib., 77 (1), pp 101-125 (July 8, 1981) 13 figs, 16 refs

Key Words: Shells, Spherical shells, Submerged structures, Fluid-induced excitation, Fluid-filled containers, Viscosity effects

In order to clarify the effect of fluid viscosity on the vibration of submerged elastic shells, the axisymmetric free oscillations of a fluid-filled spherical shell immersed in a sound field are studied. The dynamic response of the shell is determined by the classical normal mode method, while a boundary layer approximation is employed for the fluid medium. In the absence of viscosity, the shell motion is always damped due to the compressibility of the fluid outside the shell. It is shown that, except for the appearance of natural frequencies with a large damping component, the presence of surrounding fluid outside a fluid-filled shell produces only small changes in the real part of the frequency spectra. The analysis of the influence of viscosity reveals that the viscosity has essentially no effect on the frequencies of shells of moderate thickness. However, the viscous damping is predominant for the non-radiating modes of a fluid-filled submerged shell and the damping is due solely to viscosity for all modes if the outer fluid is assumed incompressible.

PIPES AND TUBES

81-2614

Comparison of LMFBR Piping Response Obtained Using Response Spectra and Time History Methods

G. Hulbert

Westinghouse Advanced Reactors Div., Madison, PA, ASME Paper No. 81-PVP-28

Key Words: Piping systems, Seismic response, Spectrum analysis

The dynamic response to a seismic event is calculated for a piping system using a response spectrum analysis method and two time history analysis methods. The results from the analytical methods are compared to identify causes for the differences between the sets of analytical results. Comparative methods are also presented which help to gain confidence in the accuracy of the analytical methods in predicting piping system structural response during seismic events.

81-2615

The Use of the Split Ring in Modeling Ductile Axial Crack Extension in Pipes

A. Emery, M. Perl, A. Kobayashi, and W. Love

Dept. of Mech. Engrg., Univ. of Washington, Seattle, WA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 151-154 (May 1981) 6 figs, 16 refs

Key Words: Pipes (tubes), Crack propagation

An earlier described ring model for the calculation of axial crack propagation in pipes is investigated numerically. The model assumes that the pipe may be divided into a series of rings. Those rings behind the crack are split and those ahead are whole. By calculating the time history of the opening of the ring behind the crack tip and relating this opening displacement to a fracture criterion, the history of the crack tip extension may be computed.

81-2616

A Sensitivity Study on Numerical Analysis of Dynamic Girth Crack Propagation

A.S. Kobayashi, A.F. Emery, W.J. Love, and A. Jain

Dept. of Mech. Engrg., Univ. of Washington, Seattle, WA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 169-174 (May 1981) 9 figs, 1 table, 20 refs

Key Words: Pipes (tubes), Crack propagation

Dynamic motion of pre-existing girth crack in an axially stressed, 18-in-diameter 316 stainless steel pipe in the presence of large-scale yielding was analyzed by a finite difference shell code. A critical crack tip opening angle (CTOA) was used as a dynamic fracture criterion and the sensitivities of dynamic crack propagation to differences in CTOA, finite differences mesh sizes, initial crack sizes and initial crack bluntnesses, were analyzed numerically. Hold-off times for the onset of dynamic crack propagation nearly doubled and tripled, while terminal crack velocities decreased about 22 percent and 47 percent when the CTOA was increased from 0.10 to 0.19 and to 0.30, respectively. Doubling of the axial length of the initial crack length and an overdriving condition simulated by a larger CTOA did not change the terminal crack velocity.

81-2617

Fluid Elastic Vibration of Tube Array in Cross Flow

H. Tanaka and S. Takahara

Aero-Hydraulics Res. Lab., Nagasaki Technical Inst., Mitsubishi Heavy Industries Ltd., Nagasaki, Japan, J. Sound Vib., 77 (1), pp 19-37 (July 8, 1981) 17 figs, 2 tables, 10 refs

Key Words: Heat exchangers, Tube arrays, Fluid-induced excitation

It is well-known that a cylinder bundle vibrates in a cross flow. Studies of the vibration have been made and it has been established that the vibration is a fluid elastic vibration. However, this theory, which is based on quasi-static fluid forces, does not always hold good for all vibration phenomena. In the theory used in this paper unsteady fluid dynamic forces are considered, which are induced by the vibrating cylinders. Since theoretical prediction of unsteady fluid dynamic forces is difficult, model tests were conducted to measure the fluid forces. The equations of motion of the cylinders were deduced and critical velocities were calculated by using the measured unsteady fluid dynamic forces. Critical velocity tests were also conducted with cylinders supported by elastic spars. The calculated critical velocities coincided well with the test results. Effects of fluid density on the critical velocity were studied and it was found that the critical velocity in a low density fluid like air is proportional to the one half power of the mass damping parameter, as predicted by the previous theory. However, the critical velocity in a high density fluid is less influenced by the mass damping parameter. The effects of detuning of the natural frequency on the critical velocity were also considered.

81-2618

Ductile Fracture of Pipes and Cylindrical Containers with a Circumferential Flaw

F. Erdogan and F. Delale

Dept. of Mech. Engrg. and Mechanics, Lehigh Univ., Bethlehem, PA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 160-168 (May 1981) 14 figs, 1 table, 20 refs

Key Words: Pipes (tubes), Fatigue life, Crack propagation, Shells

The paper deals with the problem of ductile fracture of a pipe or cylindrical container having a relatively long and deep circumferential part-through crack or a through crack and subjected to a uniform axial membrane load in the crack region. After describing the evolution of the ductile fracture process, first the results of the elasticity solution for the circumferentially cracked cylindrical shell based on the Reissner's transverse shear theory are presented. The elastic-plastic part-through crack problem is then considered. In the analysis the plastic deformations are approximated by a perfectly plastic layer similar to the conventional Dugdale model. The load carrying capacity of the cylinder is then estimated in various ways by using the crack opening stretch along the leading edge of the crack as the critical load factor.

81-2619

Continuum Solution of Simulated Pipe Whip Problem

M. Lashkari and V.I. Weingarten

Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, ASCE J. Struc. Div., 107 (ST8), pp 1443-1463 (Aug 1981) 25 figs, 1 table, 8 refs

Key Words: Pipe whip, Nuclear power plants, Piping systems

The pipe whip problem is a highly nonlinear problem which, except for special conditions, is usually solved numerically. When a dynamic load is applied to the base of a pipe (striker) whose end impacts another pipe (target), it is possible for both the striker and the target to experience plastic deformations during impact. A finite element solution considering the nonlinear impact problem with material nonlinearity has been carried out. At the point when the material becomes plastic, high frequency oscillations can set up in the continuum model. Experimental data indicate that these oscillations quickly disappear due to material damping. The effects of plasticity are considered, as are Rayleigh damping and nonlinear damping in the target material.

DUCTS

(Also see No. 2563)

81-2620

Flow-Acoustic Coupling in Ducts

P.O.A.L. Davies

Inst. Sound Vib. Res., Univ. of Southampton, Southampton, UK, J. Sound Vib., 77 (2), pp 191-209 (July 22, 1981) 10 figs, 2 tables, 22 refs

Key Words: Ducts, Discontinuity-containing media, Sound generation

Experimental data for two mechanisms of sound generation at area discontinuities in flow ducts are described and discussed. The first step in the process is the development of an ordered train of vortices in the shear layer produced by a separating flow. Though not themselves strong radiators of sound, such vortices can excite resonators strongly. The acoustic field of the resonator provides the sound waves which synchronize the vortex motion, producing a self-sustaining oscillation. Alternatively, synchronization of the vortex motion with an incident acoustic field from a source upstream can enhance the sound by transferring energy from the mean flow.

BUILDING COMPONENTS

81-2621

Effective Width of Floor Systems for Application in Seismic Analysis

F.S. Cotran and W.J. Hall

Dept. of Civil Engrg., Univ. of Illinois at Urbana-Champaign, Rept. No. STRUCTURAL RESEARCH SER-486, UILU-ENG-80-2021, NSF/RA-800428, 96 pp (Nov 1980)

PB81-168296

Key Words: Frames, Floors, Steel, Concretes, Seismic excitation

Effective width coefficients for floor systems have been developed for use in the analysis of frames subjected to lateral seismic loads. The method described covers a wide range of practical values of the slab dimensions and can be applied to both steel and concrete frames and to cases of flat slabs as well as slabs with supporting beams. The investigation is based on a parametric study of typical interior panels of floor systems, with and without supporting beams, using elastic finite element analysis to model the behavior of the floor system when the frame is subjected to lateral loads. The theoretical derivation of the method and the procedure employed for the finite element analysis is covered. Results of the study and a proposed simplified method of analysis for estimating the composite properties are presented. Simple examples illustrate application of the method, emphasizing seismic analysis and the resistance of floor systems under dynamic loads.

ELECTRIC COMPONENTS

GENERATORS

(See No. 2525)

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see Nos. 2545, 2546, 2547, 2548, 2650)

81-2622

A Comparison of Community Response to Aircraft Noise at Toronto International and Oshawa Municipal Airports

S.M. Taylor, F.L. Hall, and S.E. Birnie

Dept. of Geography, McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., 77 (2), pp 233-244 (July 22, 1981) 2 figs, 4 tables, 15 refs

Key Words: Airports, Traffic noise, Aircraft noise, Human response

Debate continues over the validity of a single dose-response relationship to describe annoyance due to transportation noise. Doubts about the appropriateness of a single relationship have centered primarily on the issue of differential response to the same noise level for different sources; e.g., aircraft, road traffic and trains. However, recent work suggests that response may vary for different types of the same source, namely aircraft, dependent upon the character, and specifically the number, of operations. Recent data collected around Toronto International and Oshawa Municipal airports permit a test of differences in four aggregate response variables. For the same NEF level, the percent at all annoyed at the two airports is not statistically different. The percent highly annoyed and the percent reporting speech interference are both significantly greater at Toronto but the percent reporting sleep interruption is greater at Oshawa. These differences can be explained in terms of the operational characteristics of the two airports.

81-2623

Industrial Noise Pollution - Part 2: Identifying and Controlling Industrial Noise Sources

R.L. Bannister

Steam Turbine-Generator Div., Westinghouse Electric Corp., Lester, PA, Mech. Engrg., 103 (8), pp 24-29 (Aug 1981) 5 figs, 30 refs

Key Words: Noise generation, Industrial facilities

It has been reported that the original proposed OSHA workplace noise standards of 85 dB would have cost industry between $18 billion and $31 billion (in 1976 dollars) to meet. The compromise standards that OSHA has now worked out will allow 90 dB but will still cost industry about $250 million. To comply with these newly established requirements, industry will have to examine everything from the design of its products to its manufacturing processes. The causes of excessive noise will have to be determined and effective and economical solutions will then have to be employed either to reduce the noise to acceptable levels or to shield the worker from its damaging impact.

81-2624

Materials for Noise and Vibration Control

W.E. Purcell

S/V, Sound and Vibration, 15 (7), pp 4-30 (July 1981)

Key Words: Materials, Noise reduction, Vibration control, Acoustic absorption, Noise barriers, Vibration damping, Vibration isolation

A comprehensive mini-handbook for the selection and application of commonly available noise and vibration control materials. Basic information is provided on the characteristics of sound absorptive, sound barrier, vibration damping, and vibration isolation materials.

81-2625

Investigation of a Parametric Acoustic Receiving Array for Mobile Applications

C.R. Clubertson, R.A. Lamb, and D.F. Rohde

Applied Res. Labs., Univ. of Texas at Austin, Austin, TX, Rept. No. ARL-TR-80-53, 40 pp (Nov 5, 1980) AD-A096 563

Key Words: Acoustic arrays, Parameter excitation, Underwater sound

The parametric acoustic receiving array (PARRAY) exploits the nonlinearity of acoustic waves in water to achieve directional reception of low frequency acoustic waves using only two high frequency transducers and associated electronics. In mobile applications the parametric receiver will be required to operate under the influence of sensor motion, and in water that is sometimes turbulent. This report describes these two areas of technical risk which are pertinent to the successful implementation of PARRAYs on submarine platforms. Analysis, fabrication, and testing of a phase-locked loop receiver is described.

SHOCK EXCITATION

81-2626

A Note on Velocity Inversion of Diffracted Waves

J.K. Cohen and N. Bleistein

Math. and Computer Science Dept., Univ. of Denver, Denver, CO 80208, Wave Motion, 3 (3), pp 279-282 (July 1981) 4 figs, 12 refs

Key Words: Wave propagation

In a recent article, the authors developed and solved an integral equation for determining small variations in propagation speed. Since the field data is high frequency data on the geophysical scale, it is important to verify that the inversion scheme correctly produces phenomena associated with high frequency data. The inversion results obtained for the case of a data set containing an edge and for the case of a data containing a buried focus are presented.

81-2627

Earthquake Research for the Safer Siting of Critical Facilities

J.L. Cluff

Natl. Academy of Sciences, Washington, DC, 59 pp (1980)

DOE/CH/93003-4

Key Words: Life line systems, Earthquake damage

The task of providing the necessities for living, such as adequate electrical power, water, and fuel, is becoming more complicated with time. Some of the facilities that provide these necessities would present potential hazards to the population if serious damage were to occur to them during earthquakes. Other facilities must remain operable immediately after an earthquake to provide life-support services to people who have been affected. The purpose of this report is to recommend research that will improve the information available to those who must decide where to site these critical facilities, and thereby mitigate the effects of the earthquake hazard.

81-2628

Effect of Earth Media on the Seismic Motion of Embedded Rigid Structures

J.J. Fedock and H.L. Schreyer

Dept. of Civil Engrg., Univ. of Santa Clara, Santa Clara, CA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 311-327 (July-Aug 1981) 11 figs, 1 table, 26 refs

Key Words: Interaction: soil-structure, Seismic waves, Seismic response

A finite element analysis is performed to determine the influence of the choice of a constitutive model for the earth medium upon the response to seismic waves of an embedded rigid structure. The seismic forcing function is characterized by Rayleigh waves with amplitude parameters adjusted to provide identical free-field motion at a surface reference point for one particular sand represented with elastic, plastic and viscoelastic models. Within the limitations of the analysis, the result is that the steady-state rigid body motions of the embedded structure are essentially identical for these constitutive relations and, consequently, it is appropriate to use an elastic representation for the earth medium.

81-2629

Dynamic Crack Propagation in Precracked Cylindrical Vessels Subjected to Shock Loading

C.H. Popelar, P.C. Gehien, and M.F. Kanninen

Dept. of Engrg. Mechanics, The Ohio State Univ., Columbus, OH, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 155-159 (May 1981) 3 figs, 1 table, 4 refs

Key Words: Cylinders, Crack propagation, Ships, Blast response

Previous work has shown that a speed-independent dynamic fracture toughness property can be used in an elastodynamic analysis to describe crack initiation and unstable propagation under impact loading. In this paper, a further step is taken by extending the analysis from simple laboratory test specimens to treat more realistic crack-structure geometries. A circular cylinder with an initial part-through wall crack subjected to an impulsive loading on its inner surface is considered. The crack is in a radial-axial plane and has its length in the axial direction long enough that a state of plane strain exists at the center of the crack. Crack growth initiation and propagation through the wall is then calculated. It is found that, once initiated, crack propagation will continue until the crack penetrates the wall. Crack arrest within the wall does not appear to be possible under the conditions considered in this paper.

VIBRATION EXCITATION

(Also see No. 2624)

81-2630

The Description of Random Vibration

J.D. Robson

Mech. Engrg. Dept., Univ. of Glasgow, UK, Intl. J. Vehicle Des., 2 (3), pp 255-275 (1981) 7 figs

Key Words: Random vibration, Structural response, Probability density function

This paper considers the whole problem of the description of random processes, with the two objects of revealing the requirements of description in their most general form and indicating in their proper context the simplifications of Gaussianity and stationarity which give rise to the most commonly used results in random vibration analysis. Single-variate processes are considered first, the additional complications of two-variate processes are then treated, and the general n-variate problem is covered.

81-2631

An Elementary Investigation of Local Vibration

R.E.D. Bishop and S. Mahalingam

Dept. of Mech. Engrg., Univ. College London, UK, J. Sound Vib., 77 (2), pp 149-163 (July 22, 1981) 8 figs, 3 refs

Key Words: Harmonic excitation

It is well known that, if a system is subjected to harmonic forced excitation, the response may be resonant only in some localized part of the system. One may refer to a resonant "subsystem" which may, or may not, be "small." The familiar reed vibrometer exemplifies a small resonant subsystem while a tuned absorber is a resonant subsystem that is not small. The implications of this are explored for the particular case of a subsystem that is linked to the remainder of the vibrating system at a single generalized co-ordinate.

MECHANICAL PROPERTIES

DAMPING

(Also see Nos. 2532 and 2565)

81-2632

An Attractive Method for Displaying Material Damping Data

D.I.G. Jones

Air Force Wright Aeronautical Labs., Wright Patterson AFB, OH, J. Aircraft, 18 (8), pp 644-649 (Aug 1981) 13 figs, 17 refs

Key Words: Damping coefficients, Damping materials, Data presentation, Nomographs

This paper describes the development of a new reduced-temperature nomogram which greatly facilitates the display and correlation of complex modulus data for a linear thermorheologically simple viscoelastic damping material in such a way that the effects of frequency and temperature can be simultaneously taken into account. The method is based on the well-known temperature-frequency equivalence principle, which allows one to modify the frequency by a factor depending on temperature alone in such a way that complex modulus data points at a given frequency and temperature can be combined into a single set of curves, representing the loss factor and modulus as a function of a single variable, known as the reduced frequency. The superimposition of temperature isotherms completes the nomogram and thereby greatly expands the usefulness of the reduced-frequency graphs by allowing display on a single graph of complex modulus data at any frequency and temperature. This allows the possibility of generating and transmitting engineering data on viscoelastic material behavior to be used in many areas where such materials are being considered for vibration control.

81-2633

Dynamic Pressure Determinations in a Squeeze-Film Damper

R. Holmes and M. Dede

School of Engrg. and Appl. Sciences, Univ. of Sussex, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 71-75, 4 figs, 8 refs

Key Words: Dampers, Squeeze film dampers, Rotors

A comparison of predicted and measured pressures in a squeeze-film damper under dynamic loading is presented. The relation between these pressures and vibration orbits resulting from rotor unbalance is elucidated.

81-2634

Theoretical and Experimental Investigation into the Effectiveness of Squeeze-Film Damper Bearings without a Centralising Spring

R.A. Cookson and S.S. Kossa

Applied Mechanics Group, Cranfield Inst. of Tech., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 359-366, 7 figs, 1 table, 10 refs

Key Words: Dampers, Squeeze film dampers, Bearings, Turbomachinery

An analytical technique has been developed for determining the effectiveness of squeeze-film damper bearings which do not have a centralizing spring. Squeeze-film damper bearings supporting both rigid and flexible rotors have been analyzed and their performance expressed in terms of non-dimensional system parameters. This analysis has indicated certain clearly defined regions, within the framework of these system parameters, in which the designer should work if he is to produce an effective vibration inhibiting device. An experimental investigation has confirmed that the squeeze-film damper bearing without a centralizing spring can be a very effective method of reducing some forms of vibration in turbomachines.

FATIGUE

(Also see No. 2519)

81-2635

Presentation of Failure Analysis Data by the Fatigue Fracture Mechanics Diagram

R.H. Sailors

American Magotteux Corp., Pulaski, TN, ASME Paper No. 81-PVP-11

Key Words: Crack propagation, Fatigue life, Graphic methods

The integrated crack growth rate equation is presented in graphical form as cyclic stress range versus initial flaw size for various constant cyclic lines. The upper bound of the graph is described by single cycle fracture and lower bound is described by an "engineering defined" threshold value of stress intensity. In many instances the fatigue fracture mechanics diagram simplifies presentation of failure analysis data. It also can illustrate the cause of failure whether it be single or multicycle, and indicate corrective measures needed to avoid repetition of the failure.

81-2636

Dynamic Fracture Initiation in Metals and Preliminary Results on the Method of Caustics for Crack Propagation Measurements

L.B. Freund, J. Duffy, and A.J. Rosakis

Brown Univ., Providence, RI, ASME Paper No. 81-PVP-15

Key Words: Fatigue life, Crack propagation, Metals

Progress is described in the use of an experimental method for studying fracture initiation under dynamic loading conditions in metals. The instrumentation provides unambiguous records of instantaneous average stress on the unfractured ligament and of instantaneous crack opening displacement.

81-2637

An Analysis of, and Some Observations on, Dynamic Fracture in an Impact Test Specimen

T. Nishioka, M. Peri, and S.N. Atluri

Georgia Inst. of Tech., Atlanta, GA, ASME Paper No. 81-PVP-18

Key Words: Fatigue life, Crack propagation, Steel

Numerical simulations of crack-propagation histories in four cases of dynamic tear test experiments on 4340 steel are performed. The influence of the loss of contact of the specimen at various times with either the supports or the tup or both is critically examined. In each case, the variation of the dynamic K-factor for the simulated crack-propagation history is directly computed.

81-2638

Evaluation of Dynamic Load Combination Fatigue Damage

Z.N. Ibrahim and S.A. Gabraiel

Sargent & Lundy Engineers, Chicago, IL, ASME Paper No. 81-PVP-20

Key Words: Fatigue life, Root mean squares

The results of the basic and parametric analyses presented in the preceding sections support the engineering practice of adopting the common cycle elimination technique to evaluate the fatigue damage of the combined, uncorrelated, simultaneous occurrences. This includes employing the square root of sum of squares of the maximum response amplitude and/or range of each of these occurrences, throughout the execution of the cycle elimination process.

81-2639

Fatigue Design in Mining Size Reduction Equipment

V. Svalbonas

Koppers Co., Inc., York, PA, ASME Paper No. 81-PVP-9

Key Words: Mines (excavations), Equipment, Fatigue life

The mining size reduction equipment industry is reviewed regarding efforts to obtain a consistent fatigue design philosophy. Serious structural failures, which have prompted various company efforts in this area, are reviewed. Basic fatigue data are being gathered with the goal of providing consistent design, fabrication and nondestructive examination programs.

81-2640

Parameters and Micromechanisms of Fatigue Crack Growth in Sheet Magnesium Alloy Samples

N.M. Grinberg and V.A. Serdyuk

Physico-Technical Inst. of Low Temperatures, Ukrainian Academy of Sciences, Lenin's Prospect, Kharkov, USSR, Intl. J. Fatigue, 3 (3), pp 143-148 (July 1981) 2 figs, 2 tables, 26 refs

Key Words: Fatigue life, Crack propagation

Growth rates of part-through and through fatigue cracks have been measured for two magnesium alloys – MA12 and IMV6 – and the micromechanisms of fatigue fracture were studied at all stages of growth. Conclusions about the peculiarities of the kinetics and micromechanisms of part-through and through crack growth, depending on the applied stress amplitudes and alloy structure, are made from a comparison of the results obtained.

81-2641

Tests to Determine the Fatigue Strength of Steel Castings Containing Shrinkage

L.P. Pook, A.F. Greenan, M.S. Found, and W.J. Jackson

Natl. Engrg. Lab., East Kilbride, Glasgow, UK, Intl. J. Fatigue, 3 (3), pp 149-156 (July 1981) 12 figs, 5 tables, 18 refs

Key Words: Fatigue tests, Steel

Fatigue tests were carried out on low strength steel castings containing deliberately introduced shrinkage defects. Failure

in most tests originated at defects which could be identified on radiographs, but on the basis of the radiographs, it would not have been possible to predict either the site of the failure or the fatigue strength of the individual specimens. Even gross center-line defects had little effect on the fatigue strength of specimens tested in four point bending, although substantially decreasing the strength of specimen tested in tension. A fracture mechanics analysis was attempted but was not satisfactory due to the difficulty in estimating the stress intensity factors for the irregular flaws concerned and because of excessive yielding in many specimens.

81-2642

Growth of Surface Fatigue Cracks in a Steel Plate

O. Vosikovsky and A. Rivard

Physical Metallurgy Res. Labs., Ottawa, Ontario, Canada, Intl. J. Fatigue, 3 (3), pp 111-115 (July 1981) 8 figs, 1 table, 11 refs

Key Words: Fatigue (materials), Crack propagation, Steel, Pipelines

The growth rates of surface fatigue cracks, both on the surface and within the plate, have been measured on an X65 pipeline steel plate. To calculate stress intensity ranges the finite-element solution by Raju and Newman has been used. The resulting fatigue crack growth rates are in good agreement with those measured on single-edge notched specimens. The variation in shape of a growing surface fatigue crack is analyzed and compared with other published measurements and analytical predictions by Nair.

81-2643

Probability of Fatigue Failure as a Statistic

A. Tsurui

Engrg. Dept., Kyoto Univ., Kyoto, Japan, Intl. J. Fatigue, 3 (3), pp 125-127 (July 1981) 7 refs

Key Words: Fatigue life, Random excitation, Statistical analysis

The probability of failure is treated as a statistic from the viewpoint that the probability can be determined only through experimental data. On the basis of a statistical theory for large samples, an asymptotic distribution function for the probability of fatigue failure under stationary random external loading is given and a simple policy for fatigue-proof design is proposed.

81-2644

Stress Intensity Factors for Fatigue Cracking of Round Bars

A.S. Salah el din and J.M. Lovegrove

Civil Engrg. Dept., Southampton Univ., Southampton, UK, Intl. J. Fatigue, 3 (3), pp 117-123 (July 1981) 11 figs, 2 tables, 18 refs

Key Words: Fatigue life, Bars

The stress intensity factor for a single edge crack of either straight or circular front in a round bar has been determined using both the degenerated quarter-point isoparametric finite element and experimental fatigue crack growth data, and compared with values found by earlier investigators. The results of this study confirm that the stress intensity factors for straight edged surface cracks are lower in round bars than in square bars and a comparison of finite element and experimental results indicates that the effective stress intensity factor at the centre of the fatigue crack front in a round bar is 17% greater than its theoretical value. A correction function is proposed to account for the effect on the stress intensity factor of the circular boundary of a round bar.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

81-2645

A New Way to Capture Elusive Signals

C. Somers

Biomation Div., Gould Inc., Santa Clara, CA, Mach. Des., 53 (10), pp 111-115 (May 7, 1981)

Key Words: Wave analyzers, Measuring instruments

Recently developed devices for capturing high-speed transient signals, the waveform recorders, are described. They are used in applications requiring high speed monitoring of multiple sensors. Monitoring of stress and strain data from high-rate dynamic tests is a typical example.

81-2646

A Matched Impedance, Electrostatic Approach to Hydrophone Design

J.A. Clark

Acousto-Optics Lab., Catholic Univ. of America, Washington, DC, J. Sound Vib., 77 (1), pp 51-59 (July 8, 1981) 4 figs, 15 refs

Key Words: Hydrophones, Sound transducers, Design techniques

A new type of acoustically transparent capacitor hydrophone is described and demonstrated. The hydrophone is built with a *dielectric material* between the capacitor plates which is similar in acoustic impedance to that of water. A theoretical model of this matched impedance type of capacitor hydrophone is developed and compared with a theory of air-filled capacitor hydrophones. Unlike the earlier air-filled types of capacitor hydrophones, the sensitivity is found to be independent of frequency and of parameters determining the capacitance of the hydrophone. Amplitude transmission ratios greater than 96% demonstrate the acoustical transparency of the device.

81-2647

Combining Holography with Speckling for Vibration Analysis

J. Politch

Dept. of Physics and Dept. of Aeronautical Engrg., Technion City, Haifa, Israel, Israel J. Tech., 18 (5), pp 275-280 (1980) 9 figs, 13 refs

Key Words: Vibration analysis, Holographic techniques, *Speckle metrology techniques, Optical methods*

Time average holographic reconstruction describes a family of fringes, proportional to contours of equal height of vibration, without being able to identify directly the "hills" and the "valleys" of the vibrating object. Time average speckle shearing interferometric reconstruction describes another family of fringes, proportional to the contours of equal slope of vibration. Combining the two families of fringes, it is possible to define at every point of a vibrating surface the amplitude and the relative phase of the mechanical vibration.

81-2648

The Acoustics of Violin Plates

C.M. Hutchins

Scientific American, 245 (4), pp 171-186 (Oct 1981)

Key Words: Violins, Musical instruments, Natural frequencies, Mode shapes, Measurement techniques

Modern tests of the vibrational properties of the unassembled top and back plates of a violin are described.

81-2649

Qualifying Fixtures for Shaker Control with a Micromodal Analyzer

L. Enochson and P.J. Traveaux

Time Series Associates, Palo Alto, CA, TEST, 43 (4), pp 14-19, 22 (Aug/Sept 1981) 15 figs, 4 tables

Key Words: Test facilities, Shakers, Vibration analysis

In a laboratory specializing in environmental vibration qualifications, a specially designed test fixture was found to cause unusual vibrations. Modal survey performed on the test fixture is described and solutions are given.

81-2650

Measurement of Transmission Loss of Panels by the Direct Determination of Transmitted Acoustic Intensity

M.J. Crocker, P.K. Raju, and B. Forssen

Ray W. Herrick Labs., School of Mech. Engrg., Purdue Univ., West Lafayette, IN, Noise Control Engrg., 17 (1), pp 6-11 (July-Aug 1981) 8 figs, 21 refs

Key Words: Panels, Sound transmission loss, Measurement techniques

A new method for the determination of the transmission loss of panels has been developed. This method involves the measurement of the incident and transmitted acoustic intensities. The incident intensity is determined from measurements of the space-averaged sound pressure level in a reverberation room on the source side of the panel. The transmitted intensity is measured directly, using a two-microphone technique. One advantage of this new method is that it uses one reverberation room instead of two as used in the conventional transmission suite method. Another advantage is that it makes possible the identification of the energy transmitted through different parts of composite panels.

DYNAMIC TESTS

(Also see Nos. 2585, 2587)

81-2651

Digital Experimental Techniques Applied to Low Frequency Shake Phenomena

J.M. O'Keeffe, W.G. Sutcliffe, I. Scheelke, and U. Proepper
SDRC-Engineering Services (UK/Scan), Ltd., SAE Paper No. 810094

Key Words: Steering gear, Vibration control, Low frequencies, Structural modification effects, Automobiles

Digital experimental techniques have been used to investigate the dynamic behavior of vehicles. A test program applied these techniques to provide design insight into low frequency shake phenomena. Operating tests defined the forces responsible for low frequency shake using narrow band spectra and order tracking techniques. Total deformation patterns were measured under operating conditions to determine the controlling elements participating in the vibration perceived at the steering wheel. Modal testing of the vehicle provided a mathematical model of the car over the frequency range 10-50 Hz. This model predicted the effect of modifications to the vehicle before they were implemented. The change in steering column response was monitored to assess the effect of these changes. Analytical predictions were confirmed by testing the modified vehicle.

81-2652

Digital Numerically Controlled Oscillator

A. Cellier, D.C. Huey, and L.N. Ma
NASA, Lyndon B. Johnson Space Ctr., Houston, TX, U.S. PATENT-4 241 308, 8 pp (Dec 23, 1980)

Key Words: Oscillators, Computer-aided techniques

The frequency and phase of an output signal from an oscillator circuit are controlled with accuracy by a digital input word. Positive and negative alterations in output frequency are both provided for by translating all values of input words so that they are positive. The oscillator reference frequency is corrected only in one direction, by adding phase to the output frequency of the oscillator. The input control word is translated to a single algebraic sign and the digital 1 is added thereto. The translated input control word is then accumulated.

81-2653

Designing Perturbed Test Tracks for Evaluating Rail Vehicle Dynamic Performance

R. Brantman, A.B. Boghani, and A.D. Little
Rail Dynamics Projects, Structures and Mechanics Branch, Transportation Systems Ctr., Cambridge, MA, ASME Paper No. 81-RT-7

Key Words: Railroad cars, Dynamic tests, Test facilities

Perturbed tracks provide a controlled means for evaluating the performance of rail vehicles in various dynamic modes, such as hunting, rock-and-roll, pitch-and-bounce, yaw-and-sway, and dynamic curving. This paper describes a systematic approach for designing such tracks and illustrates the methodology as it has been applied to the preliminary design of the tangent and curved perturbed tracks for the stability assessment facility for equipment.

81-2654

Harmonic Optimization of a Periodic Flow Wind Tunnel

J.P. Retelle, Jr., J.M. McMichael, and D.A. Kennedy
U.S. Air Force Academy, CO, J. Aircraft, 18 (8), pp 618-623 (Aug 1981) 7 figs, 1 table, 10 refs

Key Words: Test facilities, Wind tunnels, Periodic excitation

This work describes a wind-tunnel modification designed to superpose on the mean velocity sinusoidal longitudinal velocity fluctuations with minimal harmonic content. The technique is presented in light of a theoretical analysis of the low-frequency performance illustrating how harmonic suppression can be achieved with this particular design. Velocity fluctuations are produced by a system of primary rotating vanes and a bypass containing a secondary set of rotating vanes. Experimental data on tunnel performance are also presented. A significant reduction of the second harmonic content of the free-stream velocity oscillations was achieved by adjustment of the bypass flow.

DIAGNOSTICS

(Also see No. 2679)

81-2655

The Role of Sum and Difference Frequencies in Rotating Machinery Fault Diagnosis

R.L. Eshleman
Vibration Inst., Clarendon Hills, IL, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 145-149, 5 figs, 4 refs

Key Words: Diagnostic techniques, Rotating machinery, Sum and difference frequencies

Increased complexity of rotating machinery and demands for higher speeds and greater power have created complex vibration problems. Instrumentation is now available to perform sophisticated frequency analyses of complex vibration signals. This paper is concerned with correlating machinery faults to sum and difference frequencies. Such phenomena as misalignment, antifriction bearing and gear defects, oil whirl, rubs, trapped fluid, and mass unbalance can often be related to sum and difference frequencies.

81-2656

Fault Diagnosis of Gears Using Spectrum Analysis

J.I. Taylor

Vibration Specialists, Inc., Tampa, FL, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 163-168, 9 figs, 3 refs

Key Words: Diagnostic techniques, Gears, Spectrum analysis, Sum and difference frequencies

Procedures for identifying gear defects and gear meshing problems are described. A defective tooth or teeth generate and excite specific frequencies and pulses. Analysis of the time signal, spectrum frequencies, shape, amplitude, and sum and difference frequencies will reveal which gears have defective teeth, the number of defective teeth on each gear, the number of gears that have defective teeth, and the location of defective teeth with respect to some reference point. The importance of early identification of gear problems is stressed. An actual case history is presented.

81-2657

Advances in the Application of Cepstrum Analysis to Gearbox Diagnosis

R.B. Randall

Brüel & Kjaer, Naerum, Denmark, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 169-174, 7 figs, 7 refs

Key Words: Diagnostic techniques, Gearboxes, Cepstrum analysis

A review of the experience gained in the application of the cepstrum technique to the identification of families of uniformly spaced sidebands in gearbox vibration spectra is given. After a discussion of the types of faults which give rise to such sidebands, a number of practical points in the calculation and interpretation of the cepstrum are discussed. Making use of a number of practical examples, the advantages of the cepstrum are elucidated with respect to diagnostic power and repeatability (lack of sensitivity to secondary effects).

81-2658

A New Analysis Procedure for Noise and Vibration Diagnosis of Rotating Machinery

G. Hauser

Ingenieurbüro f. Technische Akustik, W. Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 381-387, 13 figs

Key Words: Diagnostic techniques, Rotating machinery, Noise source identification, Fourier analysis

The time-synchronous time-window analysis is used for noise and vibration diagnosis especially when very compact constructions with a high degree of pulses in noise behavior are examined. In order to locate noise sources, the vibrations of several channels are analyzed in short takes, so that there is an exact coordination with the mechanical process of the machine. The synchronization procedure is achieved through an angle encoder which controls the analyzing system, so that the parts of the mechanical processes are in effect close to the shaft angle in question with an exactitude of 0.1° angle and therefore independent of speed.

81-2659

Investigating Bearing Failures

J.K. Bailey, L.R. Stenander, and R.C. Cooper

TRW Bearings Div., Jamestown, NY, Power Transm. Des., 23 (8), pp 29-33 (Aug 1981)

Key Words: Bearings, Ball bearings, Failure analysis

By studying photographs, much can be learned about premature ball bearing failure that would otherwise be difficult to communicate. A graphic representation of common conditions is presented to help determine some sources of difficulty.

BALANCING

(Also see No. 2532)

81-2660

Protect Against Large Rotor Unbalance

M.L. Adams

Univ. of Akron, OH, Power, 125 (7), pp 52-54 (July 1981) 6 refs

Key Words: Bearings, Rotors, Unbalanced mass response

Two catastrophic failures initiated by large rotor unbalance in turbine/generators with fixed-arc journal bearings in fossil-fired plants are described. The data obtained by a nonlinear vibration analysis suggests that such failures could be prevented by pivoted-pad bearings.

81-2661

A Unified Approach to Flexible Rotor Balancing: Outline and Experimental Verification

M.S. Darlow, A.J. Smalley, and A.G. Parkinson

Mechanical Technology, Inc., Latham, NY, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 437-444, 6 figs, 3 tables, 13 refs

Key Words: Balancing techniques, Rotors, Flexible rotors, Unified balancing approach, Influence coefficient method, Modal balancing technique

The logical development of an improved balancing procedure is to incorporate certain features of both the influence coefficient and modal methods to combine the advantages of each while eliminating the corresponding disadvantages. Such a unified approach, Unified Balancing Approach (UBA) has been developed and verified experimentally. In this paper, the influence coefficient and modal methods are reviewed to the extent necessary to provide the basis for the unified approach. The UBA procedure is outlined emphasizing its relationship to the parent techniques, and experimental results are presented which verify the effectiveness of this balancing method and illustrate its advantages in a practical application.

81-2662

Development of High-Speed Balancing Technology - Part 1 - Effects of Laser Metal Removal on Material Properties and Part 2 - Balancing of Supercritical Shaft under Torque Load

R. DeMuth and E. Zorzi

Mechanical Technology, Inc., Latham, NY, Rept. No. NASA CR-165314, 93 pp (Jan 1981)

Key Words: Balancing techniques, Rotors, Flexible rotors

This report presents the tasks performed in the continuous high-speed balancing technology investigation to determine the effects of laser material removal on material properties and establish a balancing methodology that could control unbalance response with the application of axial torque, evaluate this methodology by experimental testing, and compare predicted and experimental results. Also covered in this report is the development, implementation, and testing of an influence coefficient approach to balancing a long, slender shaft under applied-torque conditions.

81-2663

Automatic Balancing of Rotors

A.A. Gusarov and L.N. Shatalov

GOSNII Mashinovedenia, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 457-461, 3 figs, 2 refs

Key Words: Rotors, Balancing techniques, Computer-aided techniques

Methods of automatically balancing rotors are classified. Two methods currently in use are described and some of their limitations outlined. A detailed description is given of a new technique employing a controllable electrohydraulic impact to discharge rapidly solidifying liquids on to the light side of an unbalanced rotor.

81-2664

Automatic Balancing of Grinding Wheels

H. Kaliszer

Mech. Engrg. Dept., Univ. of Birmingham, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 421-426, 8 figs, 11 refs

Key Words: Balancing techniques, Wheels, Grinding machinery, Computer-aided techniques

A detailed analysis is given of the existing balancing methods with special emphasis of automatic methods including an adaptive control of the balancing cycle. General economic aspects of selecting the most suitable balancing procedure is also given.

81-2665

Balancing of a Double Overhung Compressor with Skewed Wheels and a Bowed Shaft

D.J. Salamone, E.J. Gunter, and L.E. Barrett

Centritech Corp., Houston, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 259-264, 10 figs, 4 tables, 13 refs

Key Words: Rotors, Compressors, Balancing techniques

This paper includes the effects of a bowed shaft and skewed impeller wheels on the dynamic response and balancing of a double overhung compressor operating near the third critical speed. It is demonstrated that a two plane balance with a single correction weight at each impeller is insufficient to balance this rotor throughout the entire speed range. However, the system can be successfully balanced by the simultaneous application of couple corrections at each of the two overhung impellers.

81-2666

Balancing Flexible Rotors as a Problem of Mathematical Programming

M. Balda

Central Res. Inst., SKODA National Corp., Czechoslovakia, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 253-257, 1 fig, 2 tables, 15 refs

Key Words: Rotors, Flexible rotors, Balancing techniques, Minimax technique

It is shown that the problem of balancing flexible rotors is a problem of minimax, which is of a nonlinear nature in the general case. It may be solved either by algorithms of mathematical programming or by special algorithms for nonlinear minimax. There are cases for which the problem remains linear within particular iteration steps and may be solved as an L_p -approximation over a complex domain.

81-2667

Balancing of Flexible Rotor with Variable Mass

L.J. Cvetićanin

Technic of Sciences, V. Vlahovića, Novi Sad, Yugoslavia, Mech. Mach. Theory, 16 (5), pp 507-516 (1981) 14 figs, 18 refs

Key Words: Rotors, Flexible rotors, Balancing techniques

A method is given for balancing a flexible rotor with variable mass by use of a method for balancing a flexible rotor with constant mass. The result is a counterweight whose static mass moment varies with time.

81-2668

Processing Surplus Information in Computer Aided Balancing of Large Flexible Rotors

J. Drechsler

Balancing and Vibration Control Dept., ASEA, Sweden, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 65-69, 1 fig, 1 table, 5 refs

Key Words: Balancing techniques, Computer aided techniques, Rotors, Flexible rotors

The theory of flexible rotor balancing has thoroughly investigated the minimum number of balancing planes and the minimum amount of information necessary to successful rotor balancing. Practical experience shows, however, that a consistent consideration of surplus balancing planes and surplus information yields much better results and cuts down the production time considerably. Advanced averaging techniques on surplus trial runs and surplus balancing speeds yield a reliable influence coefficient matrix and can even be used to improve the right hand side of the equation system. The continual check on the pivot element size during the elimination process reveals how many and which planes are most suitable to reduce the vibration level. The surplus planes can be used to cut down the magnitude of the balancing weights, thus indirectly improving the rotor performance at operating speed and overspeed considerably.

81-2669

Determination of the Unbalance and the Dynamic Characteristics of a Flexible Rotor under Non-Stationary Conditions

L.N. Shatalov

GOSNII Mashinovedenia, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 453-456, 2 figs, 9 refs

Key Words: Rotors, Flexible rotors, Balancing techniques

The determination of the unbalance distribution in a flexible rotor is the most difficult part of the balancing process. Investigations in this field are usually based on considerations of stationary or quasi-stationary vibrations. However, results derived by assuming a rotor to have a constant angular velocity may turn out to be not very acceptable, even for a relatively slow passage of the rotor through its critical speed. Such a divergence between the mathematical model and the actual behavior of a rotor system may give rise to errors in the determination of the unbalance distribution in the rotor. An investigation of the dynamic characteristics of flexible rotors in terms of an amplitude-phase-frequency characteristics analysis for a fast rotor transition through a critical speed is described. The rotor behavior is described by means of differential equations for non-stationary vibrations which are solved ir terms of the asymptotic method of Bogolubov and Mitropolsky.

MONITORING

81-2670
Monitoring Rolling Contact Bearings under Adverse Conditions
A.G. Ray
Machinery Health Monitoring Group, Inst. Sound Vib. Res., Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 187-194, 8 figs, 8 refs

Key Words: Monitoring techniques, Rolling contact bearings, Bearings

A significant proportion of rolling contact bearings must be monitored under conditions that can only be considered as adverse. Low and ultra high speeds, difficulty of access and the presence of other more powerful vibration sources are three of the more commonly met situations. In these the ability of currently used techniques to detect damage falls dramatically. The author considers aspects of the above mentioned problems; first describing in some detail the physical nature of the problem, suggesting some solutions and giving two examples of successful detection: the first at low speed, less than 1000 DN, and the second of a gas turbine main bearing failure. The latter is perhaps the most interesting as it was achieved by vibration analysis of the signal from an accelerometer on the outer casing and so combined three of the worst situations.

81-2671
The Specification and Development of a Standard for Gearbox Monitoring
R.M. Stewart
Machinery Health Monitoring Group, Inst. Sound Vib. Res., Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 353-358, 3 figs, 1 table, 5 refs

Key Words: Monitoring techniques, Gear boxes

The principal objective of this paper is to "float" the idea of a monitoring standard for gearboxes. It is important to understand what such a term means in condition monitoring at the present time. It is a logical way of approaching the gearbox by appreciating the general nature of its problem, by defining and possibly proscribing the application of the various techniques at our disposal, and by laying out the sequence of steps that might be taken on the path towards implementation of a standard procedure. This paper has been written with machinery managers in mind rather than technicians in vibration analysis.

81-2672
Fine Tuning Mechanical Design
D. McCormick
Des. Engrg., 52 (8), pp 19-34 (Aug 1981) 6 figs

Key Words: Monitoring techniques, Measuring instruments

Machinery health monitoring instrumentation and its operation is described.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 2608)

81-2673
A Finite Element Formulation for Fluid-Structure Interaction in Three-Dimensional Space
R.F. Kulak

Reactor Analysis and Safety Div., Argonne Natl. Lab., Argonne, IL, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 183-190 (May 1981) 13 figs, 2 tables, 10 refs

Key Words: Interaction: structure-fluid, Finite element technique, Fluid-filled containers

A development is presented for a three-dimensional hexahedral hydrodynamic finite-element. Using trilinear shape functions and assuming a constant pressure field in each element, simple relations are obtained for internal nodal forces. Because the formulation is based upon a rate approach it is applicable to problems involving large displacements. This element is incorporated into an existing plate-shell finite element code. Diagonal mass matrices are used and the resulting discrete equations of motion are solved using an explicit temporal integrator. Results for several problems are presented which compare numerical predictions to closed form analytical solutions. In addition, the fluid-structure interaction problem of a fluid-filled, cylindrical vessel containing internal cylinders is studied.

MODELING TECHNIQUES

(Also see Nos. 2523, 2631)

81-2674

Simulation of Earthquake Ground Motions Using Autoregressive Moving Average (ARMA) Models

N.W. Polhemus and A.S. Cakmak

Dept. of Civil Engrg., School of Engrg. and Applied Science, Princeton Univ., Princeton, NJ, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 343-354 (July-Aug 1981) 7 figs, 6 tables, 11 refs

Key Words: Simulation, Earthquake simulation, Seismic excitation

Parsimonious representations of recorded earthquake acceleration time series are obtained by fitting stationary autoregressive moving average models after a variance-stabilizing transformation. Simulated acceleration series are then constructed by generating realizations from the fitted stationary models and applying the reverse transformation. As demonstrated on three components of a typical series, the response spectra for the observed and simulated series show good agreement for periods of less than eight seconds. The model parameters for the three components are very similar, suggesting a consistency which could be useful for identifying site-specific characteristics.

81-2675

Basic Course in Finite-Element Analysis - Advanced Techniques

N.F. Rieger and J.M. Steele

Stress Technology Inc., Rochester, NY, Machine Des., 53 (17), pp 97-100 (July 23, 1981)

Key Words: Finite element technique

The application of finite element technique for dynamic analysis is described.

NUMERICAL METHODS

81-2676

A New Branching Technique for the Static and Dynamic Analysis of Geared Systems

L.D. Mitchell

Mech. Engrg. Dept., Virginia Polytechnic Inst. and State Univ., Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 37-42, 5 figs, 2 tables, 13 refs

Key Words: Gears, Branched systems, Transfer matrix method

The dynamic analyses of gear-driven drive systems for their dynamic response have traditionally been done by equivalent dynamic system methods. This method and other nodal-based methods cause excessive computational bookkeeping. This paper proposes the use of multi-rotored transfer matrices. The rotors are coupled by a modified Hibner-type transfer matrix at each gear mesh. This method automatically includes the detailed bookkeeping within the matrix operations. The theory is presented, a mesh transfer matrix developed, and a benchmark example solved by conventional means and by the new coupling method. Numerical results are presented for the case of machining error in the gear teeth.

STATISTICAL METHODS

81-2677

Principle of Supplementarity of Damping and Isolation in Noise Control

G. Maidanik

David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD, J. Sound Vib., 77 (2), pp 245-250 (July 22, 1981) 2 figs, 8 refs

Key Words: Statistical energy analysis, Noise reduction, Damping effects, Isolation

The elements of the statistical energy analysis of a complex dynamic system are briefly reviewed. The explicit form of the analysis is given for a complex consisting of two basic dynamic systems. The analysis is cast in a form that underlies the principle of supplementarity of damping and isolation. Briefly, the principle states that in situations in which the application of either damping or isolation to selected strategic portions of a complex dynamic system does not perform satisfactorily in controlling a noise problem, the supplemental application of damping and isolation may perform effectively.

PARAMETER IDENTIFICATION

81-2678
Non-Parametric Identification of a Class of Non-Linear Close-Coupled Dynamic Systems
F.E. Udwadia and C.-P. Kuo
Univ. of Southern California, Los Angeles, CA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 385-409 (July-Aug 1981) 11 figs, 6 tables, 29 refs

Key Words: System identification techniques

A non-parametric identification technique for the identification of arbitrary memoryless non-linearities has been presented for a class of close-coupled dynamic systems which are commonly met within mechanical and structural engineering. The method is essentially a regression technique and expresses the nonlinearities as series expansions in terms of orthogonal functions. Whereas no limitation on the type of test signals is imposed, the method requires the monitoring of the response of each of the masses in the system. The computational efficiency of the method, its easy implementation on analogue and digital machines and its relative insensitivity to measurement noise make it an attractive approach to the non-parametric identification problem.

81-2679
The Integration of Nonlinear Stochastic Systems with Applications to the Damage and Ambiguity Identification
W. Wedig
Z. angew. Math. Mech., 61 (1), pp 7-20 (Jan 1981) 7 figs, 10 refs

Key Words: System identification techniques, Diagnostic techniques

The paper investigates nonlinear stochastic systems with piecewise linear characteristics whose multi-dimensional distribution densities are piecewise gaussian and therefore exactly calculable taking into account the necessary continuity and normalization conditions. Applying this approach to a cracked bending oscillator, a spectral analysis is performed leading to the new phenomenon that the one degree of freedom system possesses two resonances the distance of which is a measure for the damage extension.

DESIGN TECHNIQUES

81-2680
Design Sensitivity Analysis of Planar Mechanism and Machine Dynamics
E.J. Haug, R. Wehage, and N.C. Barman
Materials Div., College of Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 103 (3), pp 560-570 (July 1981) 8 figs, 5 tables, 14 refs

Key Words: Design techniques, Plane mechanisms, Optimum design, Computer aided techniques

A method of formulating and automatically integrating the equations of motion of quite general constrained dynamic systems is presented. Design sensitivity analysis is carried out using a state space adjoint variable method that has been employed extensively in optimal control and structural design optimization. Both dynamic analysis and design sensitivity analysis formulations are automated and numerical solution of state and adjoint differential equations are carried out using a stiff numerical integration method that treats mixed systems of differential and algebraic equations. A computer code that implements the method is applied to two numerical examples.

COMPUTER PROGRAMS

81-2681
Desktop Instruments for Modal Analysis
L. Enochson

Time Series Associates, Palo Alto, CA, Mach. Des., 53 (10), pp 81-86 (May 7, 1981)

Key Words: Measuring instruments, Modal analysis

Microcomputer-based desk top modal analyzers are described which can be operated by individuals unfamiliar with computer programming. In a typical modal analysis, a stick-figure model is developed to represent the geometry of the structure. The structure is then excited and the vibration data fed from transducers into the analyzer. The analyzer displays frequency-response functions from which the user determines the structural resonances where the largest deflections are produced. The analyzer then displays the animated mode shapes for these selected frequencies. By observing how the structure deforms for each of the various modes, the analyst can evaluate the stability of the structure and modify it if necessary to damp out excessive vibration.

81-2682

Evaluation of ADINA. Part I. Theory and Programing Descriptions

T.Y. Chang and J. Padovan

College of Engrg., Akron Univ., Akron, OH, Rept. No. AUE-801, 135 pp (June 8, 1980)

AD-A096 678

Key Words: Computer programs, Finite element technique

An evaluation of 1977 ADINA, a general purpose nonlinear finite element program, was conducted. The evaluation work consists of the review of its theoretical basis, nonlinear static and dynamic solution algorithms, and program architecture. A discussion of the program is made with respect to its nonlinear analysis capability and limitations.

81-2683

Evaluation of ADINA. Part II. Operating Characteristics

J. Padovan and T.Y. Chang

College of Engrg., Akron Univ., Akron, OH, Rept. No. AUE-802, 158 pp (June 8, 1980)

AD-A096 681

Key Words: Computer programs, Eigenvalue problems, Finite element technique

An advanced evaluation of the various solution algorithms available in the 1977 ADINA was made. The main objective of the evaluation work is to assess the inherent characteristics of the nonlinear static, dynamic and eigenvalue solution branches of the program. Several benchmark problems were run to establish the numerical characteristics of the solution algorithms adopted by ADINA.

81-2684

Truck and Tractor-Trailer Dynamic Response Simulation, Volume 1. Summary Report

T.D. Gillespie, C.C. MacAdam, G.T. Hu, J. Bernard, and C. Winkler

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-85-1, FHWA-RD-79-123, 22 pp (Dec 1980)

PB81-174526

Key Words: Computer programs, Articulated vehicles, Ride dynamics, Braking effects

A computer program for simulating the braking and directional response of heavy vehicles has been developed for the Federal Highway Administration as a tool for investigation of the effects of increased truck size and weight. Designated as the 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1,' the program is capable of simulating trucks, tractor-semitrailers, doubles and triples combinations. Modeling for the vehicle components has been adapted from earlier simulations produced under sponsorship of the Motor Vehicle Manufacturers Association.

81-2685

Truck and Tractor-Trailer Dynamic Response Simulation, Volume 2. Technical Report

T.D. Gillespie, C.C. MacAdam, G.T. Hu, J. Bernard, and C. Winkler

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-85-2, FHWA-RD-79-124, 130 pp (Dec 1980)

PB81-174534

Key Words: Computer programs, Articulated vehicles, Ride dynamics, Braking effects

A computer program for simulating the braking and directional response of heavy vehicles has been developed for the Federal Highway Administration as a tool for investigation of the effects of increased truck size and weight. Designated as the 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1,' the program is capable of simulating

trucks, tractor-semitrailers, doubles and triples combinations. Modeling for the vehicle components has been adapted from earlier simulations produced under sponsorship of the Motor Vehicle Manufacturers Association.

81-2686
Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:VI. Volume 3. User's Manual
T.D. Gillespie, C.C. MacAdam, and G.T. Hu
Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-38-1, FHWA-RD-79-125, 276 pp (Dec 1980)
PB81-174542

Key Words: Computer programs, Articulated vehicles, Ride dynamics, Braking effects

This document is a User's Manual for the computer-based mathematical simulation program entitled 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1' developed in 1979 by the Highway Safety Research Institute/ University of Michigan. This manual provides an introduction to the simulation program with a description of its external characteristics sufficient for a user to submit a run and interpret the output obtained.

81-2687
NORM2L: An Interactive Computer Program for Acoustic Normal Mode Calculations for the Pekeris Model
D.D. Ellis
Defence Research Establishment Atlantic, Dartmouth, Nova Scotia, Rept. No. DREA-TM-80/K, 74 pp (Dec 1980)
AD-A096 548

Key Words: Computer programs, Normal modes, Elastic waves, Wave propagation, Sound propagation, Underwater sound

The interactive computer program, NORM2L, calculates the discrete normal modes and acoustic propagation loss for the Pekeris model of the ocean. The Pekeris model is a simple two-layer model in which the two layers represent the seawater and seabed. For many shallow-water environments, the model is a reasonable approximation to the actual physical situation and can be used to investigate acoustic propagation at low frequencies. For ease of future expansion and modification, the program NORM2L is written in modular form in FORTRAN. The results of NORM2L are compared with those of other computer programs.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

81-2688
Vibrations in Rotating Machinery
Proc. of Second Intl. Conf. held at Churchill College, Cambridge, UK on Sept 1-4, 1980, organized by the Applied Mechanics Group of the Institution of Mechanical Engineers, 461 pp

Key Words: Proceedings, Rotating machinery, Bearings, Shafts, Mechanical drives, Gear drives, Balancing techniques

Papers presented at this conference include the seismic response of flexible rotors, modal dynamic simulation of flexible shafts in hydrodynamic bearings, drive trains in printing machines, vibration spectra from gear drives, balancing of flexible rotors as a problem of mathematical programming, and many others. Abstracts of individual papers are listed in the appropriate sections of this issue of the Digest.

TUTORIALS AND REVIEWS

81-2689
A 'Road Map' for Stress Analysis
T.G. Krulick
Fuller Co., Bethlehem, PA, Mach. Des., 53 (18), pp 139-143 (Aug 6, 1981)

Key Words: Stress analysis

Procedures for solving various stress problems are presented by means of three charts. Chart A shows how to handle static loads in both brittle and ductile materials. Chart B covers reversing loads on ductile structures. Chart C treats fluctuating loads, uniaxial or combined, in ductile materials.

81-2690

Three Traps to Avoid in Noise Control

T.H. Rockwell

Acoustical Consultant, Chesterland, OH, Plant Engrg., 35 (16), pp 99-100 (Aug 6, 1981) 2 figs

Key Words: Noise reduction, Machinery vibration, Machinery noise

The aim of this article is to clarify some of the acoustics fundamentals of machinery noise control. It briefly discusses sound absorption, machinery vibration and noise measuring instrumentation.

CRITERIA, STANDARDS, AND SPECIFICATIONS

81-2691

Logical Analysis of Tentative Seismic Provisions

J.R. Harris, S.J. Fenves, and R.N. Wright

Ctr. for Building Tech., U.S. Dept. of Commerce, Natl. Bureau of Standards, Gaithersburg, MD, ASCE J. Struc. Div., 107 (ST8), pp 1629-1641 (Aug 1981) 6 figs, 2 tables, 4 refs

Key Words: Standards and codes, Buildings, Seismic design, Earthquake resistant structures

A study is described of the format and expression of the Tentative Provisions for the Development of Seismic Regulations for Buildings developed by the Applied Technology Council. The methods of analysis employed provide objective measures of clarity, completeness and consistency, as well as an alternative formal representation with which to examine the correctness of the provisions. The formal representation of the seismic provisions and the findings of the analysis will assist those concerned with the future development of the provisions and their implementation within the various national standards and model codes.

ANNUAL AUTHOR INDEX

B

C

D

E

F

G

I

J

K

L

N

O

P

S

U

V

W

X

Y

Z

ANNUAL SUBJECT INDEX

A

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Elastic Half-Space
2400 252 1936
2312

Elastic Media
2490 2191 1302 413 405 1086 1059
1552 1983 1526 1319

Elastic-Plastic Properties
361 664 126
1344 1066
1346

Elastic Properties
252 1345 86 837
426 997
2606 1347
1527
2397

Elastic Waves
1300 171 713 974 145 136 847 388 389
991 733 1034 1035 1046 1697 848 1699
1301 1043 1044 1045 1696 1827 1698
1961 1303 1294 1305 2446 1967 2028
2181 2443 1304 1695 2447 2448
2421 1374 2687
1514
2444

Elastically Restrained Edges
100

Elasticity
1789

Elasticity Theory
996 1107

Elastodynamic Response
2202 1527

Elastohydrodynamic Properties
2594

Elastomeric Bearings
2574 1646
1886

Elastomeric Dampers
831 656

Elastomeric Seals
2594

Elastomers
2570 631 1885 1886 2097 58
1651 2526 1528

Elastoplastic Properties
2260 2172 45 1349

Electric Drives
532

Electric Generators
use Electric Power Plants

Electric Power Plants
791 394 25 26 887 28
1811 1415 386 1427 208
1146 738
1416 1488
2548

Electric Systems
2530

Electric Vehicles
233 899

Electromagnetic Properties
1814

Electronic Instrumentation
1734 626 1357
696

Elevated Railroads
919
1439

Enclosures
1030 1031 2602 943 14 816 98 1029
1013 1028

Energy Absorbers
use Energy Absorption

Energy Absorption
1880 1222 904 45 906 1637 789
1990 2092 2094 755 1426 2097
2352 2354 905 1636
2355

Energy Dissipation
902 103 2184 1195
2192 1873 1805

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Failure Detection

	2471	2402	2403	2404		696		2018	2289
				2444					

Fan Blades

950			1533						

Fan Noise

	1581						2047		
	1861						2297		

Fans

1580	951		1413	1174	525	226	517	68	
	1581		1533	1414	875	526	727		
	1811		1853	1784	1415	726	1427		
							1957		
							2567		

Fast Fourier Transform

		2012		674		526			69
				1364		2086			1089

Fast Fourier Transformation
use Fast Fourier Transform

Fatigue Life

470	1	12	163	64	165	326	227	238	599
600	41	1342	1083	164	265	836	317	258	659
660	191	1992	1163	224	285	856	327	1188	1219
1200	211	2222	1343	834	895	1186	1187	1218	1719
1440	321		1603	894	1085	1566	1617	1298	2109
1660	481		1993	1084	1625	2016	1717	1348	2439
1720	661		2303	1524	1645	2636	1787	1438	2519
1870	791		2373	1544	1795		1837	1718	2639
2220	1111		2643	1564	2635		2077	1788	
2440	1341			1834			2107	1938	
2460	1371			1994			2117	2368	
	1871			2304			2367	2438	
	1991			2644			2427	2618	
	2221						2637	2638	

Fatigue (Materials)

1530		162			835				659
		2642							

Fatigue Strength
use Fatigue Life

Fatigue Tests

680	2441		1083	1084	205	236	237	438	1189
	2641		2343	1344	325	916	327		2369
				2374	835	1346	437		
					1085	1546	1347		

(cont'd)

Fatigue Tests (continued)

					1185				
					1345				
					1525				
					2375				

Feedback Control

						1116			

Fiber Composites

340		612		2354	2355		2297	88	2149
		1342					2407	998	2439

Fiberglass

			2183						

Fiberscopes

						176			

Field Test Data

1630				1204					

Filters

2460	1731	2002	2003						179
	2471	2472							

Finite Difference Technique

		862	123	84	2155	1496	2227		939
		1642				1506			
						1656			

Finite Difference Theory
use Finite Difference Technique

Finite Displacement Method

			963		1375				

Finite Element Technique

250	1	142	343	4	365	46	37	8	99
460	361	362	353	114	455	196	77	68	459
730	1131	492	403	364	505	246	1277	398	469
750	1381	722	453	454	855	346	1387	408	539
760	1711	732	663	474	1005	556	1477	418	749
780	2321	862	783	884	1375	706	1687	458	969
860	2491	892	813	974	1595	736	1937	878	989
890	2551	1132	843	984	1935	776	2127	928	1119
1010		1642	1033	1484	2025	1056	2177	1438	1219
1130		1672	1293	1914	2275	1086	2377	1478	1269
1150		2082	1393	2274	2555	1126		2058	1279
1330		2102	1463	2294	2675	1506		2088	1909
1410		2282	1963	2504		1826		2128	1929
1950		2512	2053	2604		2126		2138	1979
1960		2682	2283			2166		2148	2019

(cont'd)

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

- H -

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

- J -

- L -

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Motors

1360	161	1042	1693	1694	2525	2526		528	
		1092		2524					

Mountings

		5562				756	1177		
						2526			

Moving Loads

730	2191	12		1854	775	1906	2127	8	1659
1820		1002		1984	2385		2397	1588	2129
1890		1682						1668	
		2122						2128	
								2258	
								2418	

Mufflers

1470	1471	1472	393	304			1397		
			1883	1234					
				1884					

Multibeam Systems

	1021		373	344	345		377	378	
								1288	

Multidegree of Freedom Structures
use Multidegree of Freedom Systems

Multidegree of Freedom Systems

820	1761	572	1713	1524		2496		898	409
2300			2493	1714					829

Multifrequency Testing Techniques

2240									

Multiplane Balancing Technique

	1741								

Multipocket Bearings

				1644					

Multipole Analysis

	141								

Multistory Buildings

1990	731	1822	2063			2536			
	1081	2392							
	1921								

Musical Instruments

								2648	

- N -

Nastran (Computer Programs)

1150	1151			364	2275	556	2037	2038	2039
2040	2321								
2590									

Natural Frequencies

110	11	92	63	4	765	596	87	38	109
350	101	112	113	84	985	986	337	528	1249
1000	1261	982	223	114	1005	1006	417	558	1299
1010	1661	1262	323	124	1205	1246	867	878	1549
1800	1831	1662	1193	234	1905	1776	987	1028	1559
1910	1931	1672	1913	384	1925	1926	1257	1118	2159
1940	2061	1922	1943	454	2115	2266	1287	1178	2269
2150	2361	2082	2393	1904		2386	1657	1278	2239
2510		2132	2483	1924			1917	1428	2599
		2202	2523	2054			2137	1678	
				2294			2197	1888	
				2484			2347	1898	
				2494				2058	
								2648	

Natural Vibrations

		492					1937		

Newmark Method

					1135				

Noise Barriers

810	811	1882	633	2624	55	146	147	808	149
			1973		2545		807	1308	809
									919

Noise Control
use Noise Reduction

Noise Generation

2290	311	82	283	394	135	226	137	328	19
2340	2051	392	813		395	816	887	628	329
	2551	812	1033		555	926	1307	1418	269
		1202	1413		815	1196	1487	1568	1179
		1512	2323		1225	1486	2307	1818	1469
		1952	2333			1586	2547		1509
		2332	2623						1879

Noise-Induced Excitation

							1497		

Noise Measurement

670	1451	1202	143	144	815	1446	1877	908	169
1810	1531	1352	753	814	1215	1616	2007	1088	909

(cont'd)

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

- P -

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Propellant Tanks
2013

Propeller Blades
1720 311 1152 953 524 1175 2557 939
2340 2102 1153 874 1585 1229
1463 954
1583 1624
2344

Propeller Induced Excitation
1532 116

Propeller Noise
931 143 1615 1616
2341 283
1863

Propellers
1720 931 555 1576 2557

Proximity Probes
1726 2457 2458
2456

Pulleys
2300

Pulse Excitation
1270 801 612 2403 374 1315 1556 1687 2298 1669
1670 1762 1324 2396 1919
1680 2402 1654
1900 2404
2424

Pulse Test Method
2011 2242

Pumping
804

Pumps
10 591 582 3 504 515 1026 587 228 9
520 2291 602 473 1354 1416 508 519
1582 2533 518 529
2052 528 839
1108 1179
1538
1738

- Q -

Quadratic Damping
2095

Quartz Resonators
107

Quasilinearization Technique
850 859

- R -

Racks
1916

Radiation Efficiency Method
1047

Rail Transportation
917

Railroad Cars
690 691 183 34 35 206 207 1438 59
1850 921 273 64 65 1436 1437 1249
2653 1434 1435
2564

Railroad Tracks
2090 1852 2075 256 1659

Railroad Trains
20 1851 715 549
23[illegible]1 1849

Railroad Transportation
use Rail Transportation

Railroad Vehicles
use Railroad Trains

Rails
use Railroad Tracks

Railway Vehicles
use Railroad Trains

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1674	1675-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Rotors (continued)

2360	2511	2592	2523			2666			2669
2510	2521	2662	2593						
2530	2531		2633						
2660	2661		2663						

Rotors (Machine Elements)
use Rotors

Rubber
use Elastomers

Runway Roughness

290	1461							288	289

- S -

Safety Belts
use Seat Belts

Safety Restraint Systems

2330	181	1222					277		
		1632					2327		

Sand

						2466	1197		

Sandwich Laminates
use Sandwich Structures

Sandwich Panels
use Panels and Sandwich Structures

Sandwich Structures

	341	2602			2395			1928	2139
	2141								2219

SAP (Computer Programs)

			813						

Satellite Antennas
use Spacecraft Antennas

Satellites

								1128	

Saws

		2362			2055	2056			1479

Scaling

2250			183	634	925		1737		
				1604					

Screws

600									599

Seals

		1582	603	604	605	336	1537	2118	959
		2592	2593	764	2585	606	1897		
				2594	2595	716	2117		
						2106			
						2596			

Seat Belts

	181	1632					2327		

Seismic Analysis

1590	261	882	1283		1255			1198	1779
	1601	1502	2383		1915				
	2171	2312							

Seismic Barriers

								2068	

Seismic Design

240	241	792	153	384	735	16	17	248	379
1320	261	1422	253	794	1195	216	1167	468	479
	2601	2192	1143	1144	1825	376	1777	1158	1399
	2691		2193		1835	1166	2317	1318	2309
					2195	1916		1398	

Seismic Detectors

								2078	

Seismic Excitation

250	821	242	1983	154	1705	416	737	1158	1279
	1661	892	2383	684	2135	736	2097	1498	2189
	2621	1072	2433	1144		796		1948	
		1962		2064		2066		2098	
		2062		2674				2178	

Seismic Isolation

60							2097	2098	

Seismic Response

30	251	372	773	24	15	386	27	28	29
260	771	772	783	344	25	806	257	368	239
370	891	782	793	764	545	1706	267	688	259
400	2311	822	883	804	795	1916	847	798	399
800	2531	1022	893	824	825	2136	2177	1038	799
820		2392	1193	884	1385			1518	889

(cont'd)

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-886	887-1167	1168-1402	1403-1674	1675-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1674	1675-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1674	1675-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

- T -

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13 Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

- W -

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

TECHNICAL NOTES

A. Leissa and Y. Narita
Vibrations of Free Circular Plates Having Elastic Constraints and Added Mass Distributed along Edge Segments
J. Appl. Mechanics, Trans. ASME, 48 (1), pp 196-198 (Mar 1981) 3 figs, 6 refs

M.A.M. Torkamani
Method of Direct Solution to Inverse Problems
ASCE J. Engrg. Mechanics Div., 107 (2), pp 424-429 (Apr 1981) 2 figs, 6 refs

P.R. Brazier-Smith, D. Butler, and J.R. Halstead
The Determination of Propagation Path Lengths of Dispersive Flexural Waves through Structures
J. Sound Vib., 75 (3), pp 453-457 (Apr 8, 1981) 4 figs, 4 refs

S.M. Correa, D.L. Sengupta, and W.J. Anderson
Inflight Aircraft Vibration Modes and Their Effect on Aircraft Radar Cross Section
J. Aircraft, 18 (4), pp 318-319 (Apr 22, 1981) 4 figs, 6 refs

J.R. Kuttler and V.G. Sigillito
On Curve Veering
J. Sound Vib., 75 (4), pp 585-588 (Apr 22, 1981) 2 figs, 2 tables, 4 refs

C.T. Leung, N.W.M. Ko, and K.H. Ma
Heat Transfer from a Vibrating Cylinder
J. Sound Vib., 75 (4), pp 581-582 (Apr 22, 1981) 1 fig, 4 refs

S.V. Kulkarni and K.B. Subrahmanyam
Reissner Method Calculations of Natural Frequencies of Torsional Vibrations of Tapered Cantilever Beams
J. Sound Vib., 75 (4), pp 589-592 (Apr 22, 1981) 2 tables

T. Irie, G. Yamada, and M. Tsujino
Natural Frequencies of Concavely Shaped Polygonal Plates with Simply Supported Edges
J. Acoust. Soc. Amer., 69 (5), pp 1507-1509 (May 1981) 2 figs, 1 table, 10 refs

R.E. Mickens
A Uniformly Valid Asymptotic Solution for $d^2y/dt^2 + y = a + \epsilon y^2$
J. Sound Vib., 76 (1), pp 150-152 (May 8, 1981) 8 refs

J.S. Bandat
Spectral Bandwidth, Correlation Duration, and Uncertainty Relation
J. Sound Vib., 76 (1), pp 146-149 (May 8, 1981) 2 refs

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION
ACTA MECHANICA Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Acta Mech.
ACUSTICA S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1 W. Germany	Acustica
AERONAUTICAL JOURNAL Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. J.
AERONAUTICAL QUARTERLY Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. Quart.
AIAA JOURNAL American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	AIAA J.
AMERICAN SOCIETY OF CIVIL ENGINEERS, PROCEEDINGS ASCE United Engineering Center 345 East 47th St. New York, NY 10017	
JOURNAL OF ENGINEERING MECHANICS DIVISION	ASCE J. Engrg. Mechanics Div.
JOURNAL OF STRUCTURAL DIVISION	ASCE J. Struc. Div.
AMERICAN SOCIETY OF LUBRICATING ENGINEERS, TRANSACTIONS Academic Press 111 Fifth Ave. New York, NY 10019	ASLE, Trans.
AMERICAN SOCIETY OF MECHANICAL ENGINEERS, TRANSACTIONS ASME United Engineering Center 345 East 47th St. New York, NY 10017	
JOURNAL OF APPLIED MECHANICS	J. Appl. Mechanics, Trans. ASME
JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME
JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engrg. Indus., Trans. ASME
JOURNAL OF ENGINEERING FOR POWER	J. Engrg. Power, Trans. ASME
JOURNAL OF ENGINEERING RESOURCES TECHNOLOGY	J. Engrg. Resources Tech., Trans. ASME
JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech., Trans. ASME
JOURNAL OF MECHANICAL DESIGN	J. Mech. Des., Trans. ASME
JOURNAL OF PRESSURE VESSEL TECHNOLOGY	J. Pressure Vessel Tech., Trans. ASME
APPLIED ACOUSTICS Applied Science Publishers, Ltd. Ripple Road, Barking Essex, UK	Appl. Acoust.
ARCHIVES OF MECHANICS (ARCHIWUM MECHANIKI STOSOWANEJ) Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Arch. Mechanics
ASTRONAUTICS AND AERONAUTICS AIAA EDP 1290 Avenue of the Americas New York, NY 10019	Astronaut. & Aeronaut.
AUTOMOBILTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Abteilung Technik 7000 Stuttgart 1 Pfizerstrasse 5-7 W. Germany	Automo- biltech. Z.
AUTOMOTIVE ENGINEER (SAE) Society of Automotive Engineers, Inc. 400 Commonwealth Drive Warrendale, PA 15096	Auto. Engr. (SAE)
AUTOMOTIVE ENGINEER (UK) P.O. Box 24, Northgate Ave. Bury St., Edmunds Suffolk IP21 GBW, UK	Auto. Engr. (UK)
BALL BEARING JOURNAL (English Edition) SKF (U.K.) Ltd. Luton, Bedfordshire LU3 1JF, UK	Ball Bearing J.
BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.
BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES Ars Polona-Ruch 7 Krokowskie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.

PUBLICATION AND ADDRESS	ABBREVIATION
BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS Japan Society of Mechanical Engineers Sanshin Hokusei Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan	Bull. JSME
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826 Berkeley, CA 94705	Bull. Seismol. Soc. Amer.
CIVIL ENGINEERING (NEW YORK) ASCE United Engineering Center 345 E. 47th St. New York, NY 10017	Civ. Engrg. (N.Y.)
CLOSED LOOP MTS Systems Corp. P.O. Box 24012 Minneapolis, MN 55474	Closed Loop
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers Struc.
DESIGN ENGINEERING Berkshire Common Pittsfield, MA 02101	Des. Engrg.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Des. News
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P.O. Box 7406 Milwaukee, WI 53213	Diesel Gas Turbine Prog.
ENGINEERING MATERIALS AND DESIGN IPC Industrial Press Ltd. 33-40 Bowling Green Lane London EC1R, UK	Engrg. Mtl. Des.
ENGINEERING STRUCTURES IPC Science and Technology Press Ltd. Westbury House P.O. Box 63, Bury Street Guildford, Surrey GU2 5BH, UK	Engrg. Struc.
EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P.O. Box 277 Westport, CT 06880	Exptl. Mechanics
FEINWERK U. MESSTECHNIK Carl Hanser GmbH & Co. D-800 Munchen 86 Postfach 860420 Fed. Rep. Germany	Feinwerk u. Messtechnik
FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139 Graf-Recke Str. 84 4 Düsseldorf 1 W. Germany	Forsch. Ingenieurwesen

PUBLICATION AND ADDRESS	ABBREVIATION
HEATING/PIPING/AIR CONDITIONING Circulation Dept. 614 Superior Ave. West Cleveland, OH 44113	Heating/ Piping/ Air Cond.
HYDRAULICS AND PNEUMATICS Penton/IPC, Inc. 614 Superior Ave. West Cleveland, OH 44113	Hydraulics & Pneumatics
HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
INGENIEUR-ARCHIV Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Ing. Arch.
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS IEEE United Engineering Center 345 East 47th St. New York, NY 10017	IEEE
INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminster, London SW1, UK	IMechE Proc.
INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222	ISA Trans.
INSTRUMENTATION TECHNOLOGY Instrument Society of America 67 Alexander Drive P.O. Box 12277 Research Triangle Park, NC 27709	InTech.
INTERNATIONAL JOURNAL OF CONTROL Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK	Intl. J. Control
INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016	Intl. J. Earthquake Engrg. Struc. Dynam.
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engrg. Sci.

PUBLICATION AND ADDRESS	ABBREVIATION
INTERNATIONAL JOURNAL OF FATIGUE IPI Science and Technology Press Ltd. P.O. Box 63, Westbury House, Bury Street Guildford, Surrey, England GU2 5BH	Intl. J. Fatigue
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlin. Mechanics
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engrg.
INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS John Wiley and Sons, Ltd. Baffins Lane Chichester, Sussex, UK	Intl. J. Numer. Anal. Methods Geomech.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Solids Struc.
INTERNATIONAL JOURNAL OF VEHICLE DESIGN The International Assoc. of Vehicle Design The Open University, Walton Hall Milton Keys MK7 6AA, UK	Intl. J. Vehicle Des.
ISRAEL JOURNAL OF TECHNOLOGY Weizmann Science Press of Israel Box 801 Jerusalem, Israel	Israel J. Tech.
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.
JOURNAL OF AIRCRAFT American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Aircraft
JOURNAL OF THE AMERICAN HELICOPTER SOCIETY American Helicopter Society, Inc. 30 East 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.
JOURNAL OF ENGINEERING MATHEMATICS Academic Press 198 Ash Street Reading, MA 01867	J. Engrg. Math.
JOURNAL OF ENVIRONMENTAL SCIENCES Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
JOURNAL OF FLUID MECHANICS Cambridge University Press 32 East 57th St. New York, NY 10022	J. Fluid Mechanics
JOURNAL OF THE FRANKLIN INSTITUTE Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
JOURNAL OF HYDRONAUTICS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Hydronautics
JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA Science House, 157 Gloucter Sydney, Australia 2000	J. Inst. Engr., Austral.
JOURNAL DE MECANIQUE Gauthier-Villars C.D.R. - Centrale des Revues B.P. No. 119, 93104 Montreuil Cedex-France	J. de mecanique
JOURNAL OF MECHANICAL ENGINEERING SCIENCE Institution of Mechanical Engineers 1 Birdcage Walk, Westminster London SW1 H9, UK	J. Mech. Engrg. Sci.
JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mechanics Phys. Solids
JOURNAL OF PETROLEUM TECHNOLOGY Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206	J. Pet. Tech.
JOURNAL OF PHYSICS: E SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	J. Phys. E: Sci. Instrum.
JOURNAL OF SHIP RESEARCH Society of Naval Architects and Marine Engineers 20th and Northhampton Sts. Easton, PA 18042	J. Ship Res.
JOURNAL OF SOUND AND VIBRATION Academic Press 111 Fifth Ave. New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Spacecraft Rockets
JOURNAL OF TESTING AND EVALUATION (ASTM) American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	J. Test Eval. (ASTM)
KONSTRUKTION Spring Verlag 3133 Connecticut Ave., N.W. Suite 712 Washington, D.C. 20008	Konstruktion
LUBRICATION ENGINEERING American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068	Lubric. Engrg.
MACHINE DESIGN Penton Publishing Co. Penton Bldg. Cleveland, OH 44113	Mach. Des.
MASCHINENBAUTECHNIK VEB Verlag Technik Oranienburger Str. 13/14 102 Berlin, E. Germany	Maschinen-bautechnik
MECCANICA Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Meccanica
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 East 45th St. New York, NY 10017	Mech. Engrg.
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mechanics Res. Comm.
MECHANISM AND MACHINE THEORY Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engrg. Kyoto Univ.
MTZ MOTORTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Pfizerstrasse 5-7 7000 Stuttgart 1 W. Germany	MTZ Motor-tech. Z.
NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bldg. 1012 - 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.

PUBLICATION AND ADDRESS	ABBREVIATION
NOISE AND VIBRATION CONTROL Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Vib. Control
NOISE CONTROL ENGINEERING P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603	Noise Control Engrg.
NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS, TRANSACTIONS Bolbec Hall Newcastle upon Tyne 1, UK	NE Coast Instn. Engrs. Shipbldrs., Trans.
NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P.O. Box 3489 Amsterdam, The Netherlands	Nucl. Engrg. Des.
OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne Tulsa, OK 74101	Oil Gas J.
PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engrg.
PLANT ENGINEERING 1301 S. Grove Avenue Barrington, IL 60010	Plant Engrg.
POWER P.O. Box 521 Hightstown, NJ 08520	Power
POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	Power Transm. Des.
QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mechanics Appl. Math.
REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MECANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumaine 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mecanique Appl.
REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.
SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.
SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.

PUBLICATION AND ADDRESS	ABBREVIATION
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.
STROJNICKY ČASOPIS Red. Strojnickeno Casopisu ČSAV A SAV USTAV MECHANIKY STROJOV SAV Bratislava-Patronka, Dubrovska cesta, ČSSR Czechoslovakia	Strojnicky Časopis
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviat Rd. Bay Village, OH 44140	S/V, Sound Vib.
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen-ATM
TEST 61 Monmouth Road Oakhurst, NJ 07755	Test
TRIBOLOGY INTERNATIONAL IPC Science and Technology Press Ltd. Westbury House P.O. Box 63, Bury Street Guildford, Surrey GU2 5BH, UK	Tribology Intl.
TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.
VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Düsseldorf 1, Germany	VDI Z.
VDI FORSCHUNGSHEFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Düsseldorf 1, Germany	VDI Forsch.
VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
VIBROTECHNIKA Kauno Polytechnikos Institutas 2 Donelaičio g-ve 17 233000 Kaunas Lithuanian SSR	Vibro-technika
WAVE MOTION North Holland Publishing Co. P.O. Box 211 1000 AE Amsterdam The Netherlands	Wave Motion
WEAR Elsevier Sequoia S.A. P.O. Box 851 1001 Lausanne 1, Switzerland	Wear
ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepziger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	Z. Flugwiss

SECONDARY PUBLICATIONS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION
GOVERNMENT REPORTS ANNOUNCEMENTS & INDEX NTIS U.S. Dept. of Commerce Springfield, VA 22161	GRA
SCIENTIFIC AND TECHNICAL AEROSPACE REPORTS *Superintendent of Documents* U.S. Government Printing Office Washington, D.C. 20402	STAR
DISSERTATION ABSTRACTS INTERNATIONAL University Microfilms Ann Arbor, MI 48106	DA

ANNUAL PROCEEDINGS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION
INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.
TURBOMACHINERY SYMPOSIUM Gas Turbine Labs Texas A&M University College Station, Texas	Turbomach. Symp.
THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Center Naval Research Lab., Code 5804 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.

CALENDAR

FEBRUARY 1982

22-26 SAE Congress and Exposition [SAE] Detroit, MI *(SAE Hqs.)*

MARCH 1982

29-Apr 1 Design Engineering Conference and Show [ASME] Chicago, IL *(ASME Hqs.)*

30-Apr 1 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Oak Brook, IL *(Ronald L. Eshleman, Director, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)*

APRIL 1982

14-16 Fatigue Conference & Exposition [SAE] Dearborn, MI *(SAE Hqs.)*

18-22 Gas Turbine Conference and Products Show [ASME] London, England *(ASME Hqs.)*

20-22 Mechanical Failures Prevention Group 35th Symposium [National Bureau of Standards] Gaithersburg, MD *(Dr. James G. Early, National Bureau of Standards, Bldg. 223/Room A-113, Washington, DC 20234 - (301) 921-2976)*

20-23 Institute of Environmental Sciences' 28th Annual Technical Meeting [IES] Atlanta, GA *(IES, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)*

22-23 13th Annual Pittsburgh Conference on Modeling and Simulation [School of Engineering, Univ. of Pittsburgh] Pittsburgh, PA *(William G. Vogt or Marlin H. Mickle, Modeling and Simulation Conf., 348 Benedum Engrg. Hall, Univ. of Pittsburgh, Pittsburgh, PA 15261)*

26-30 Acoustical Society of America, Spring Meeting [ASA] Chicago, IL *(ASA Hqs.)*

MAY 1982

12-14 Pan American Congress on Productivity [SAE] Mexico City *(SAE Hqs.)*

24-26 Commuter Aircraft and Airline Operations Meeting [SAE] Savannah, GA *(SAE Hqs.)*

JUNE 1982

7-11 Passenger Car Meeting [SAE] Dearborn, MI *(SAE Hqs.)*

JULY 1982

13-15 'Environmental Engineering Today' Symposium and Exhibition [SEE] London, England *(SEE, Owles Hall, Buringford, Herefordshire, UK)*

19-21 12th Intersociety Conference on Environmental Systems [SAE] San Diego, CA *(SAE Hqs.)*

AUGUST 1982

16-19 West Coast International Meeting [SAE] San Francisco, CA *(SAE Hqs.)*

SEPTEMBER 1982

13-16 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI *(SAE Hqs.)*

OCTOBER 1982

4-6 Convergence '82 [SAE] Dearborn, MI *(SAE Hqs.)*

4-7 Symposium on Advances and Trends in Structural and Solid Mechanics [George Washington Univ. and NASA Langley Res. Ctr.] Washington, DC *(Prof. Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Res. Ctr., Hampton, VA 23665 - (804) 827-2897)*

12-15 Stapp Car Crash Conference [SAE] Ann Arbor, MI *(SAE Hqs.)*

25-28 Aerospace Congress & Exposition [SAE] Anaheim, CA *(SAE Hqs.)*

NOVEMBER 1982

8-12 Acoustical Society of America, Fall Meeting [ASA] Orlando, Florida *(ASA Hqs.)*

8-12 Truck Meeting & Exposition [SAE] Indianapolis, IN *(SAE Hqs.)*

14-19 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Phoenix, AZ *(ASME Hqs.)*

*U.S. GOVERNMENT PRINTING OFFICE: 1981-0-361-334 206

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, NJ 07645
AGMA:	American Gear Manufacturers Association 1330 Mass Ave., N.W. Washington, D.C.
AHS:	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, NY 10019
AIChE:	American Institute of Chemical Engineers 345 E. 47th St. New York, NY 10017
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, IL 60605
ARPA:	Advanced Research Projects Agency
ASA:	Acoustical Society of America 335 E. 45th St. New York, NY 10017
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, NY 10017
ASME:	American Society of Mechanical Engineers 345 E. 45th St. New York, NY 10017
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, IL 60202
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, WI 53203
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103
CCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada
ICF:	International Congress on Fracture Tohoku Univ. Sendai, Japan
IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, NY 10017
IES:	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056
IFToMM:	International Federation for Theory of Machines and Mechanisms U.S. Council for TMM c/o Univ. Mass., Dept. ME Amherst, MA 01002
INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
ISA:	Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222
ONR:	Office of Naval Research Code 40084, Dept. Navy Arlington, VA 22217
SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096
SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, UK
SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, CT 06880
SNAME:	Society of Naval Architects and Marine Engineers 74 Trinity Pl. New York, NY 10006
SPE:	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 5804 Washington, D.C. 20375
URSI-USNC:	International Union of Radio Science - U.S. National Committee c/o MIT Lincoln Lab. Lexington, MA 02173

PUBLICATIONS AVAILABLE FROM
THE SHOCK AND VIBRATION INFORMATION CENTER
CODE 5804, Naval Research Laboratory, Washington, D.C. 20375

	PRICES Effective - 1 September 1981 U.S.	FOREIGN
SHOCK AND VIBRATION DIGEST		
SVD-14 (Jan. - Dec. 1982)	$140.00	$175.00
SHOCK AND VIBRATION BULLETINS		
SVB-47	$ 15.00	$ 18.00
SVB-48	30.00	37.50
SVB-49	30.00	37.50
SVB-50	60.00	75.00
SVB-51	100.00	125.00
SVB-52	140.00	175.00
SHOCK AND VIBRATION MONOGRAPHS		
SVM-2, Theory and Practice of Cushion Design	$ 10.00	$ 12.50
SVM-4, Dynamics of Rotating Shafts	10.00	12.50
SVM-5, Principles and Techniques of Shock Data Analysis	5.00	6.25
SVM-6, Optimum Shock and Vibration Isolation	5.00	6.25
SVM-7, Influence of Damping in Vibration Isolation	15.00	18.75
SVM-8, Selection and Performance of Vibration Tests	10.00	12.50
SVM-9, Equivalence Techniques for Vibration Testing	10.00	12.50
SVM-10, Shock and Vibration Computer Programs	10.00	12.50
SVM-11, Calibration of Shock and Vibration Measuring Transducers	25.00	31.25
SVM-12, Balancing of Rigid and Flexible Rotors	50.00	62.50
SPECIAL PUBLICATIONS		
An International Survey of Shock and Vibration Technology	$ 30.00	$ 37.50
The Environmental Qualification Specification as a Technical Management Tool	12.00	15.00

To order any publication, simply check the line corresponding to that publication that appears below, and mail the postage free card. You will be invoiced at the time of shipment.

Please send the following publication(s) to me:

____
Name

____
Address

____

Mail invoice to: (if other than above)

____

____

____

___ SVD-14
___ SVB-47
___ SVB-48
___ SVB-49
___ SVB-50
___ SVB-51
___ SVB-52
___ SVM-2
___ SVM-4
___ International Survey
___ Qual. Spec. Report
___ SVM-5
___ SVM-6
___ SVM-7
___ SVM-8
___ SVM-9
___ SVM-10
___ SVM-11
___ SVM-12

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY, CODE 5804
SHOCK AND VIBRATION INFORMATION CENTER
Washington, D.C. 20375

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316

U.S.MAIL

The Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington D.C. 20375

PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].
>
> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined
- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- volume, number or issue, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (1962).
4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).
5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).
7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

Articles for the DIGEST will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the DIGEST. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 1500 to 2500 words in length. For additional information on topics and editorial policies, please contact:

Milda Z. Tamulionis
Research Editor
Vibration Institute
101 West 55th Street, Suite 206
Clarendon Hills, Illinois 60514

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY, CODE 5804
SHOCK AND VIBRATION INFORMATION CENTER
Washington, D.C. 20375

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316

THE SHOCK AND VIBRATION DIGEST

Volume 13, No. 12 — December 1981